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Abstract

We examine retail gasoline station pricing using three years of weekly prices for 272 stations in the Virginia suburbs of Washington, DC. We report a number of new empirical findings about station level pricing and describe how these findings relate to existing models of retail pricing. First, we find retail margins change substantially over time (by more than 50%) while the shape of the margin distribution remains relatively constant. Second, the distribution of retail gasoline prices has relatively thick tails. Third, stations frequently change their relative prices and margins. Fourth, there is substantial heterogeneity in pricing behavior: stations charging very low or high prices are more likely to maintain their pricing position than stations charging prices near the mean, even when controlling for permanent differences in marginal costs.

JEL Codes: D4, L44, L81

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1.0 Introduction

The recent increases in the price of gasoline have focused attention on all levels of the gasoline supply chain, from refining to retail. Following Hurricane Katrina retail prices jumped more than 50 cents per gallon in a matter of days in some cities leading to claims of 'gouging'. In response to these price spikes the U.S. Congress has considered legislation that would provide civil and criminal sanctions for price gouging.[1] In contrast, states have expressed concern about new retail formats (primarily supermarkets and mass merchandisers) selling gasoline at too *low* of a price. In response to these concerns, some states have modified or increased enforcement of their "sales below cost" laws or *minimum* markups laws.[2]

The increased concern about gasoline pricing has increased the demand for understanding how retail gasoline prices are determined and how they change over time. Previously, large panel data sets of station specific gasoline prices have generally not been available. Recently, however, credit card (i.e., "fleet card") transaction data, has enabled researchers (and allows us) to examine the pricing behavior of a large number of gasoline stations over an extended period of time.

We use a three year panel data set of weekly gasoline prices on nearly three hundred gasoline stations located in the Northern Virginia suburbs of Washington, DC to establish a number of new empirical findings about retail gasoline pricing. We go on to relate these findings to the existing theoretical literature on pricing behavior, and suggest deficiencies in these existing theories in explaining retail gasoline pricing.

Our first finding is that the retail markup (defined as retail price less a measure of wholesale price and taxes) for gasoline shows sizeable changes over time and these changes are persistent. In other words there are sizeable regime changes in average margins. For instance, in our sample the weekly median margin is more than 17 cents per gallon for 26 consecutive weeks (the mean of the median is 19.4 cents) in 1997 and 1998 before falling to

[1] Many states already have price gouging statutes. Following Hurricane Katrina more than 100 gasoline stations were investigated by states for price gouging. See: U.S. Federal Trade Commission "Investigation of Gasoline Price Manipulation and Post-Katrina Gasoline Price Increases," May, 2006.
[2] At least six states (Alabama, Kansas, New York, Michigan, Virginia, and Wisconsin) have considered legislation that would have introduced or modified minimum markup or sales below costs laws on gasoline. See FTC staff letter to The Honorable Gene DeRossett, Michigan House of Representatives, June 2004. http://www.ftc.gov/os/2004/06/040618staffcommentsmichiganpetrol.pdf

less than 14 cents a week (the mean of the median is 10.7 cents) for 12 weeks. While the changing margins can be partially explained by asymmetric price adjustment, our empirical work suggests that equilibrium margins may be changing as well.

Second, we find that the distribution of prices across stations (either within a local area or at a particular point in time) has thick tails. Although roughly 70% of stations charge prices that are within 3.5 cents of the mean, some stations charge prices much different than the mean, with 3.5% of stations charging prices that are more than 10 cents different than the mean. This is somewhat contrary to economic intuition, which suggests that a fairly homogenous product, like gasoline, where search costs are relatively low (prices are prominently posted, and consumers are in their cars while searching) would have low price dispersion.

Third, we find that stations do not appear to use simple static pricing rules: stations do not charge a fixed mark-up over their wholesale costs, nor do they maintain their relative position in the pricing distribution over time. Instead, a particular gasoline station frequently changes its relative position in the pricing distribution, often dramatically. From one week to the next, stations are more likely than not to change their relative position measured in either dollars (above or below the mean in a given week) or rank (price relative to closest stations). There is, however, heterogeneity in station's pricing decisions. Stations that charge very high or very low prices in one period are much more likely to charge high or low prices in subsequent periods. Interestingly, there appears to be an asymmetry in this behavior. Stations charging low prices appear to remain low priced stations for much longer periods than high priced stations. Surprisingly, while some stations consistently charge relatively high or low prices, station characteristics (other than brand affiliation) and measures of localized competition are not good predictors of this heterogeneity.

Fourth, while there is heterogeneity in a station's pricing decision: with some stations charging systematically high or low prices, a significant fraction of stations choose to change their typical position in the pricing distribution from year to year, sometimes dramatically. We find that roughly 30% of stations change their "typical price" (defined as a station's mean price relative to the mean price in Northern Virginia) significantly from one year to the next. Between 1997 and 1998 nearly 25% of gasoline stations changed their relative position in the pricing distribution by more than 20 percentile points, e.g., moving from the 70th percentile to the 50th percentile. In fact, between those years 4% of stations moved more than *50* percentile points in the pricing distribution. This suggests that gasoline stations repositioned themselves, sometimes substantially, over relatively short periods of time.

Constrained by the data at hand, researchers have historically examined either inter-temporal or inter-station price variation. The research on intertemporal variation, often referred to as the "rockets and feathers" literature, examines pricing data at various levels of the industry (i.e., spot, rack and retail) usually aggregated over large geographic areas to examines the price response of gasoline at one level, e.g. retail, to a change in price at another level, e.g. wholesale. Some papers in this literature find that retail prices increase more quickly following increases to wholesale prices than decreases, (see, e.g., Borenstein et al (1997)), while others (e.g. Galeotti et al. (2003)) find the opposite result. The results of this literature are mixed and seem to depend on the time aggregation of the data (daily, weekly, or monthly), the level of the industry examined (refining, distribution, or retail), and the estimation technique. Although we find some statistical evidence of asymmetric adjustment, we find that this modeling approach leaves important features of the data unexplained.

The research on inter-station price variation uses station-level data either as a single-period cross-sectional or a short panel.[3] These papers have found that much of the inter-station variation retail price can be explained by brand affiliation, some measures of localized competition (typically a measure of localized station density and/or distance to the closest rival), and a handful of station attributes (e.g., if the station also performs repairs, has a convenience store, or offers full service gasoline). Our results suggest that these findings may not be robust across different time periods or geographic locales.

Our paper belongs to a relatively nascent (but rapidly growing) group of papers which lies at the convergence of these two branches of the empirical gasoline pricing literature and uses relatively long panels of weekly (or daily) station-level pricing data to examine the dynamics of station-level pricing behavior. Eckert and West (2004a), verify that station-level dynamics are important, finding that aggregated weekly price data masks substantial meaningful variation across stations and within weeks. Lewis (2005a) verifies that the "rockets and feathers" pattern is present in station-level data in Southern California.

The remainder of paper is organized as follows. The next section provides some very brief institutional detail about gasoline retailing and describes our data. Section three

[3] For examples of papers examining retail gasoline pricing in a cross section or short panel see, Slade (1992), Shepard (1990, 1991, 1993), Barron et al. (2000, 2004), and Hastings (2004).

presents our empirical findings. Section four discusses the various models of pricing behavior most likely to be applicable to retail gasoline. Section five relates these theoretical models to our empirical findings. Section six concludes and presents possible avenues for further work.

2.0 Background and Data

Gasoline stations are retailers. They receive gasoline from a distributor (sometimes vertically integrated) and resell it to consumers. Like other retailers, gasoline stations compete on prices, quality (location, cleanliness, speed of pumps), and bundles of services (convenience store, repair services). There are, however, a number of important characteristics of gasoline retailing that differentiate it from other types of retailing. First, the issue of consumers purchasing "bundles" of products is less important to gas stations than to other types of retailers, such as food or clothing. Virtually every consumer entering a gas station purchases gasoline while only a subset will purchase other goods (beer, cigarettes, or repair services).[4] Because a low price on gasoline is attractive to *every* potential consumer, the price of gasoline takes on a much more strategic role than the pricing of other products sold by the gas station.[5] Second, relative to many other products, gasoline is fairly homogeneous which facilitates consumer search. Any brand of gasoline of a given octane[6] will run an automobile. Taken together, these factors suggest consumer search for gasoline is easier than many other retail goods.

One advantage of studying gasoline retailing is that some measures of marginal cost are observable. Wholesale or "rack" prices for branded and unbranded gasoline are observable.[7] The gas stations that purchase branded gas at the rack are owned and operated

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[4] For example, convenience stores, which represent the largest retail channel of gasoline sales in the U.S. (roughly 75% of gasoline sales), report that gasoline sales represent roughly 69.5% of convenience store revenues in 2003. National Association of Convenience Stores web page, visited 1/31/07.

[5] Lal and Matutes (1994) develop a model describing how retailers selling bundles of products will charge low prices on a subset of products in the bundle to attract consumers. Hosken and Reiffen (2004) extend the Lal and Matutes model to show that the items likely to be offered at low prices will be those in most consumers bundles.

[6] 87 octane gasoline accounted for 69% of gasoline sold in the U.S. in 1999 (EIA).

[7] The wholesale distribution point in gasoline markets is typically refereed to as the "rack", referring to the distribution point where the trucks obtain the gasoline that is delivered to retail stations. The terms rack and terminal are often used synonymously. The terminal is the point where gasoline is stored before distribution to retail stations. The terminal contains a truck "rack."

by individuals who, in essence, operate franchises. Other firms (sometimes the same firms selling branded gasoline, sometimes firms acting purely as distributors) will post unbranded prices for gasoline that will be sold at stations unaffiliated with a brand.

There are, however, two other channels of gasoline distribution for which marginal cost are unobserved. Stations that are owned and operated by a refiner (i.e., completely vertically integrated) "pay" an unobserved transfer price for gasoline. There are also a significant number of "lessee dealer" stations in Northern Virginia. These stations are owned by the refiner but operated by separate entities.[8] These stations pay an unobserved wholesale price for gasoline that is determined by the refiner. In addition, the wholesale price paid by different lessee dealers operating in the same metropolitan area may vary.[9] Thus, at any time, there may be a number of different marginal costs across stations within the same region. We follow the literature in viewing the posted rack prices as the opportunity cost of gasoline, since refiners and distributors choose to sell at that price.

The stations we examine are located in the Northern Virginia suburbs of Washington DC. This region likely contains the set of all important competitors in the retail sale of gasoline in Northern Virginia. While Northern Virginia is in the same metropolitan area as both Washington DC and Suburban Maryland, commuting patterns and the prevailing relative prices of gasoline in the three areas likely negates the impact of pricing in Maryland and DC on stations in Virginia. The regions in Virginia beyond our sample area likely do not contain many important competitors because there are very few stations in the regions with very little population.

Our data come from three sources. First, we have a three year panel of prices for 272 stations in Northern Virginia. This data comes from the Oil Price Information Service ("OPIS"), and are generated from fleet card[10] transaction data. We also have data from OPIS on the wholesale prices of both branded and unbranded gasoline.

We also have a census of all the location and attributes of all of the roughly 600 stations in Northern Virginia for each of the years, 1997, 1998, and 1999. This data comes

[8] In Virginia refiners can not build new company owned and operated gasoline stations. However, at the time the law forcing vertical separation was passed in 1979 (divorcement), refiners were allowed to continue to operate the stations they owned.

[9] See Meyer and Fischer (2004) for an extensive description of lessee dealer pricing.

[10] Fleet cards are often used by firms whose employees drive a lot for business purposes, e.g., salesman or insurance claims adjusters. Fleet cards are often used to closely monitor what items employees charge to the firm.

from New Image Marketing, and consists of annual surveys of stations' addresses, attributes (e.g., whether the station has service bays, a convenience store, and the number of pumps), and a description of the station's vertical relationship with its supplier. While we do not observe the pricing of all stations, we are able to construct variables measuring the competitive environment each of the stations in our sample faces. Specifically, we calculate measures of station density (the number of stations located within different mileage bands of our sampled station) and the distance to the closest station.

Finally, we obtained information on neighborhood characteristics (measured at the zip-code level) from the U.S. Census. These variables, which include median household income, population, and population density, are from the 2000 census and correspond to conditions in 1999.

We examine three different measures of price. The retail price of gasoline is the price recorded at the pump (including taxes) for the most commonly sold variation of gasoline (87 octane). We use the average "branded rack" as our measure of wholesale price. This is defined as the average price of all of the "branded" gasoline's offered at the rack in a week. We have chosen the branded rack as our benchmark measure of wholesale price because the majority of stations sell a branded product. Our results, however, are robust to the choice of rack price.[11] Finally, we define a station's mark-up (margin) to be the retail price less the branded rack price and taxes. Thus, a station's margin corresponds to its incremental profit.

Descriptive statistics for the data used are presented in Table 1. The break down of station affiliations in our sample is presented in Table 2.

3.0 Results

In this section we describe some empirical regularities in retail gasoline pricing and establish the paper's key findings. First, we find that the distribution of retail margins within a region shifts dramatically over time. While our data is consistent with a pattern of asymmetric price adjustment (price increasing being passed through more quickly than price decreases), our findings suggest this explanation is incomplete. Second, we find that the

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[11] Branded rack prices are the wholesale prices sold under the name of the refiner providing the gasoline, (such as Texaco, Exxon, or Mobil). Unbranded rack prices are the prices charged by a distributor (often, but not always a refiner) but sold under the name of an independent gasoline retailer (Bob's Gasoline). During our sample period branded gasoline is typically a few cents per gallon more than unbranded gasoline.

distribution of retail gasoline prices has relatively thick tails. Third, we find that stations do not appear to follow simple pricing rules: both their margins and their prices relative to each other fluctuate over time. While there is systematic heterogeneity in some stations' pricing, e.g., stations consistently charging relatively high or low prices, station characteristics (other than brand affiliation) and measures of localized competition are not good predictors of this heterogeneity. Fourth, we find that the systematic component of a station's pricing decision (the station's average relative price) changes, often substantially, from year to year.

3.1 Finding 1: Retail Margins Vary Substantially Over Time

Retail margins vary dramatically over time. Figure 1 shows the branded rack price of gasoline and the plot of the 25th, 50th, and 75th percentiles of the distribution of gasoline stations' retail margins (retail price less wholesale prices and taxes) by week from 1997 through 1999. During this time period the average retail margin was 14.4 cents per gallon, as high as 20.9 cents per gallon (in 1999), and as low as 5.7 cents (also in 1999). The figure also shows that the entire pricing distribution tends to shift over time; i.e., the spread between the 25th and 75th percentile is fairly stable, roughly 4 cents per gallon in 1997, and 5 cents in 1998 and 1999.

Although the margins in our dataset vary over time, they also exhibit a high degree of persistence. For example, the median margin is more than 17 cents per gallon for 26 consecutive weeks (averaging 19.4 cents) in 1997 and 1998 before falling to less than 14 cents per gallon (averaging 10.7 cents) for 12 weeks. Obviously, the change in retail profits associated with this change in margin is sizeable. While we do not observe output, it is reasonable to assume that changes in quantity are relatively small (gasoline demand is very inelastic), while the margin fell by 50%.[12]

[12] Our finding of dramatic changes in retail margins is potentially consistent with recent empirical research on asymmetric price adjustment in retail gasoline markets sometimes referred to as the "rockets and feathers" literature (see, e.g., Borenstein et al. (1997) and Lewis (2005a)). These papers find that increases in wholesale gasoline prices are passed through more quickly than wholesale price decreases. While there is some statistical evidence of asymmetric pass through of wholesale costs in our data, the coefficients of estimated asymmetric price adjustment model were not economically plausible and differed substantially from those found in the existing literature (see section 5.4 for an extensive discussion).

3.2 Finding 2: The distribution of retail gasoline prices has relatively thick tails.

Relative to many other consumer products, we expect that the search costs associated with purchasing gasoline are low. Although retailers are differentiated by physical location (proximity to an interstate or relative isolation) and station attributes (having a large convenience store), gasoline is fairly homogenous: any brand of gasoline (of a given octane) will work in an automobile. Indeed, the only technical differentiation across brands is the chemicals added to the gasoline before it is delivered to the station. Further facilitating search, consumers are in their cars while shopping for gas and gasoline prices are prominently posted outside stations. Taken together, these factors suggest that there should be relatively little dispersion in gasoline prices across a region at a point in time.

The wholesale price of gasoline is very volatile. At the beginning of our sample the wholesale price of gasoline is approximately 75 cents per gallon. In early 1999 it fell to 35 cents before rising back to 75 cents per gallon in late 1999. To control for changes in costs, we define retail price variation as deviations about the mean price at a point in time. Specifically, we analyze price dispersion by examining the residuals from the following regression:

$$(1) \quad \mathrm{p}_{it} = \mathrm{a}_0 + \sum_t \gamma_t (\text{Week Indicators}_t) + \mathrm{e}_{it}$$

where $p_{i,t}$ is station *i*'s gasoline price in week t, and the γ_t are the coefficients corresponding to weekly indicators. We estimate equation (1) using data for each station for each time period. The frequency distribution of the estimated error terms (e_{it}) is presented in Figure 2. We find that most prices are very close to the mean: 56% and 71% of prices are within 2.5 cents and 3.5 cents of the mean, respectively. However, the tails are quite thick, e.g., roughly 3.5% of prices are more than 10 cents from the mean. To facilitate interpretation of these findings, we also plot a normal frequency distribution with the same mean and standard deviation as the observed residuals (mean zero, standard deviation of 3.99 cents). If the residuals were normal, we would expect to see 47% and 62% of prices within 2.5 and 3.5

cents of the mean, and 1.2% of prices more than 10 cents from the mean. We can easily reject the null that the residuals have a normal distribution.[13]

The general pattern seen for the pooled data also holds when looking at the residuals separately by year.[14] While the shape of the distribution differs somewhat across years (prices appear less disperse in 1997 than either 1998 or 1999), most gasoline prices are very close to the mean: 75%, 69% and 66% are within 3.5 cents of the mean in 1997, 1998 and 1999. Further, the tails are thick: roughly 2% of prices are more than ten cents from the mean in 1997 and 4% of prices are more than ten cents from the mean in 1998 and 1999.[15] An implication of this finding is that models estimated using maximum likelihood and an assumption that errors are normally distributed may yield inefficient parameter estimates, see, e.g., White (1982).

3.3 Finding 3: Stations Do Not Appear to Follow Simple Pricing Rules

We have established that in each week, retail gasoline prices are fairly tightly distributed about the mean price, and that some stations charge very different prices than the mean price. Furthermore, we have shown that the markups that stations charge change substantially (by 50%) and stay at very different levels for relatively long periods of time. However, despite significant changes in retail margins and gasoline prices over time, the shape of the distribution of prices about the median margin at a point in time does not change very much – during our sample period the interquartile range is typically between 3 and 6 cents. This leads to a natural question: is the gasoline pricing distribution stable over time? That is, do individual stations pick a price relative to their rivals and maintain that price, or do stations change their relative position in the pricing distribution over time?
We find that gasoline stations appear to change their *relative* prices frequently. While some stations appear to charge systematically higher or lower prices, relative prices change

[13] The kurtosis of the residual distribution is 6.07, the p-value for the test of normality is essentially zero (calculated using the sktest command in Stata). A normal random variable has a kurtosis of 3, variables with a kurtosis greater than 3 are said to be leptokurtic.

[14] See Appendix Figures 1-3.

[15] Again, assuming residuals were normally distributed with standard deviations equal to the observed standard deviations, the expected proportion of prices within 3.5 cents of the mean would be: 68%, 60% and 59% in 1997, 1998 and 1999 and the proportion of prices more than 10 cents from the mean would be 0.5%, 1.6%, and 1.9% in 1997, 1998 and 1999. The residual distributions in 1997, 1998, and 1999 have kurtosis of 9.21, 5.45, and 4.55. In each year, we reject the null of normality of the residual distribution with a p-value of essentially zero.

frequently. Finally, in contrast to many previous papers, station characteristics (other than brand affiliation) do not explain much of a station's average relative pricing.

Unlike most other retailers, gasoline stations face sizeable and frequent shocks to their wholesale costs. These large cost shocks force gasoline retailers to change their price frequently. Relative to other retailing environments,[16] costs are disproportionably the cause of changes in retail gasoline prices. However, while changing the price they charge, gasoline stations may also reevaluate how they wish to price *relative* to their rivals. Again, in contrast to other types of retailing, the cost to a gasoline station of determining its relative price is very low: its rivals post their prices on huge signs in front of their stores.

In documenting and analyzing the relative prices we used three related empirical approaches. First, we analyze how a given gasoline station's relative price changes between consecutive time periods (controlling for changes in the overall price level). Second, we analyze how a given gasoline station's relative price changes between consecutive time periods, controlling for both changes in the overall price level and a station's systematic pricing behavior (such as permanent differences in marginal costs). Finally, we analyze how the relative position (rank) of a gasoline station changes between weeks relative to its closest rivals.

We begin by analyzing a firm's relative price changes over time. Specifically, we define a firm's relative price in week t to be the residual from equation (1); i.e., the difference between station i's price in week t and the mean price of all stations in our sample in week t. We round the residual to the nearest cent and construct a Markov transition matrix where the elements of the matrix show the probability of being y cents above (below) the mean in period $t+1$ conditional on being x cents above (below) the mean in period t. The matrix is presented in Appendix Table 1, however, a more intuitive understanding of the information in the matrix can be seen from plotting the data (see Figure 3). Figure 3 shows the frequency distribution of a station's price in period $t+1$ conditional on its price in period t. For example, if a station's price in period t is less than 10 cents below the mean in period t there is an 80% probability that its price will be at least that low in period $t+1$.

[16] Chevalier et al (2003) and Hosken and Reiffen (2004) find that in food retailing, most changes in retail prices are likely the result of retail price competition rather than changes in wholesale costs; that is, retailers (and manufacturers of branded consumer goods) play pricing games that cause retail prices to change over time independent of changes in wholesale prices. In clothing retailing, predictable fashion cycles also generate price variation independent of changes in wholesale costs (Pashigan (1988)).

There are two key findings from the figure. First, there is persistence in gasoline stations' relative prices. The modal choice of a station is to maintain its relative pricing position from week to week; i.e., if a station is 4 cents below the mean in period *t* it is most likely to be 4 cents below the mean in period *t+1*. Second, despite this persistence, for all but two of the frequency distributions, the mode is less than 50%.[17] Thus, more than 50% of the time a station's relative price will change by at least one cent each week. The shape of the frequency distributions of stations charging low prices in period *t* looks very different than stations charging high prices in period *t*. Stations charging relatively low prices in period *t* have higher modes and more probability mass very close to the mode than those stations charging relatively high prices. This suggests that stations charging high prices are converging to the mean more quickly than stations charging low prices. Thus, in contrast to food retailing where retailers periodically offer low prices and normally charge high prices, the transition matrix shows that gas stations periodically charge high prices, but do not maintain abnormally high prices for very long. However, low prices appear to be more persistent; that is, a subset of stations appear to charge everyday low prices.

The findings from Figure 3 suggest there is systematic heterogeneity in pricing across stations over time. To examine the importance of this heterogeneity in explaining retail gasoline pricing we control for both time effects and time invariant station effects in regression (3) below,

$$\text{(2)} \quad \mathrm{p}_{it} = \sum_i \theta_i (\text{Station Indicators}_i) + \sum_t \gamma_t (\text{Week Indicators}_t) + e_{it}$$

where the θ_i are gasoline station specific fixed-effects. This corresponds to a model where stations pursue a static pricing strategy where their markups are a function of their (time-invariant) observed and unobserved attributes (as measured by the θ_i's). The interpretation of the residuals from equation (2) is very different than equation (1). For example, e_{it} is now the deviation from station *i*'s pricing in period *t* after controlling for station *i*'s time-invariant idiosyncratic pricing behavior. Thus, if we observe persistence in a station's residual, e_{it}, then the station is systematically charging higher or lower prices *than its typical price* for some

[17] For these two cases, the empirical distribution of prices in *t+1* conditional on prices at time t being either 10 cents or more above the mean or 10 cents or less below the mean, are not directly comparable to the other cases – in these two cases the set of prices we are conditioning on corresponds to a much broader range of prices.

period of time. Not surprisingly, equation (2) explains more of the variation in retail pricing than (2), e.g., the R-squared increases from 0.88 to 0.95 in moving from equation (1) to (2). Furthermore, by adding the time-invariant station effects, we are able to explain most of the large deviations in stations' prices. This can be seen in Figure 4, which plots the residuals from regression 2, and shows that only 0.9% of residuals are more than 10 cents from the mean (compared to 3.4% from the regression in equation (1)).

Figure 5 presents the Markov transition matrix corresponding to the residuals from equation (2) and is constructed analogously to Figure 3.[18] The interpretation of Figure 5, however, is very different. Figure 5 shows the probabilities of transitions between consecutive weeks where prices are measured relative to a specific *station's* average price (rather than relative to the average price in Northern Virginia as in Figure 3). For example, in Figure 5 we see that a station that is charging a price 5 cents more than its mean price in week t is predicted to be charging a price 5 cents more than its mean in week t+1 with probability .31. There are two notable differences between Figures 3 and 5. First, controlling for a station's typical pricing (θ_i) explains a great deal of the persistence in pricing. This can most clearly be seen by the decrease in the modal prices in moving from Figure 3 to Figure 5. While the modal price charged in week t+1 is the price charged in t in both figures, this mode is much lower in Figure 5 than Figure 3 (and this difference is greatest for prices more than a few cents from the mean). Second, there is quicker convergence to the mean in Figure 5. A station charging a price above its *own* mean is predicted to return to its *own* mean price more quickly that a station charging a higher price than the *region's* mean is predicted to return to the *region's* mean price. It is interesting to note, however, that even controlling for a station's average pricing, the predicted pricing distribution at time t+1 depends on t; that is, pricing decisions are inherently dynamic.

The previous analysis has compared prices over a relatively large geographic area. While this analysis is informative, it potentially misses some important aspects of localized competition. For example, in densely populated Northern Virginia, it is unlikely that a gas station considers the prices of stations 10 miles away when setting its prices. More likely, the set of relevant stations that factor in the price-setting process is likely relatively narrow, consisting of the set of stations "nearby". It is easy to imagine that stations develop simple

[18] Appendix Table 2 contains the matrix corresponding to Figure 5.

pricing rules within these regions, such as maintaining the second lowest price among the ten closest stations, or being 3 cents lower than a store with a prime location.

We examine localized pricing by determining each station's price position relative to its 9 closest rivals each week (where a rank of 1 corresponds to having the lowest price and 10 corresponds to having the highest).[19] To illustrate what a station's rank looks like over time, we begin by plotting the weekly price ranks of all of the Crown stations in our data set (see Figure 6). The figure shows a clear pattern: Crown stations tend to charge very low relative prices. Stations 6, 7, 8, and 14 are almost always charging the lowest prices of the ten closest stations. While the relative ranking of some Crown stations is more variable (stations 2 and 5), the typical Crown station appears to charge among the lowest prices of its nearby competitors.

Because it is not feasible to examine the relative rank series for every station in our sample we create an aggregate measure analogous to that used to examine a station's relative price. Specifically, we examine how a station's rank changes from week to week by constructing a Markov transition matrix and presenting it in a figure with the same interpretation as Figures 3 and 5. The pattern that emerges in Figure 7 is very similar to what we see in examining week to week price changes using the sample of relative prices from all of Northern Virginia. First, the modal strategy for a firm is to maintain its relative pricing position from week to week. Firms that charge very low or very high prices, however, appear very different than those charging prices near the median of the distribution: stations that charge very high or very low prices in one week are very likely to charge very high or very low prices in the next week. Stations charging prices close to the median of the distribution (a rank of 4, 5, 6, or 7) are much more likely to change relative position from week to week. We find the same pattern holds when viewing stations prices relative to a narrower group of stations, comparing them to their four closest rivals (see Figure 8). Stations charging low or high prices in one week (rank 1 or 5) are much more likely to be charge those prices in the subsequent week than stations charging prices near the median (ranks 2, 3, and 4).

3.3.1 Estimating a Station's Idiosyncratic Pricing Function

[19] Our price data corresponds to a sample of stations rather than the population. Therefore we analyze the prices relative to a station and the 9 closest stations *in our sample*. This set of stations potentially differs from the 9 closest in the population.

Many prior studies which examine localized gasoline pricing have been limited to either cross-sectional or a short panel of data.[20] These data limitations have forced researchers both to use observable characteristics rather than station fixed effects, and to assume that the relationship between stations' prices and their measurable characteristics are relatively constant over time.[21] The richness of our dataset allows us to evaluate the robustness of these assumptions. In general, we find that observable characteristics (other than a station's brand affiliation) do a poor job of controlling for station-specific pricing.

We begin by estimating a specification including the key control variables from the literature. Specifically we estimate a station's retail margin in each week (markup over the wholesale price of branded gas) as a function of station attributes, demographics corresponding to the zip code the station is located in,[22] indicators for the brand of gasoline sold, localized competition, and the vertical relationship between the station and its gasoline supplier as in equation (3) below where *i* is the store index and *t* refers to a given week.[23]

$$\begin{aligned}(3)\quad \text{Margin}_{it} = \alpha_0 &+ \sum_k \beta_k (\text{Station Characteristics}_{it}) + \sum_k \gamma_k (\text{Localized Competition Variables}_{it}) \\ &+ \sum_k \delta_{ki} (\text{Demographics}_{it}) + \sum_k \theta_k (\text{Brand Indicator}_{it}) \\ &+ \sum_k \pi_k (\text{Vertical Relationship}_i) + \sum_t \lambda_t (\text{Year}_t) + \text{e}_{it}\end{aligned}$$

The results from this equation are shown in the first column of Table 3. Consistent with the literature, we find that brand effects are very important predictors of retail margins. Interestingly, we find that although the station's demographic environment (median household income, population, and population density) are important predictors of margins, none of the stations' physical attributes (e.g., having a convenience store) appear to be important predictors. The estimated coefficients on the stations' physical attributes are both statistically and economically (all less than a penny) insignificant.

The remaining columns of Table 3 report the estimates when we allow the coefficients to vary across years. A few findings are worth noting. First, the estimated

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[20] Eckert and West (2004a, 2004b), Lewis (2005a, 2005b) and Noel (2007a) are notable exceptions.

[21] The goal of most of these studies is not to accurately measure the returns to different station characteristics or the coefficients on brand affiliation. In most cases, the authors are trying to control for other factors that affect gasoline prices and include these characteristics as control variables. In some of the short panel studies, (such as, Hastings (2004)), authors use station level fixed-effects as controls.

[22] Because gasoline stations likely draw customers from a region larger than a census block, we use zip code level measures of the demographic variables.

[23] Because individual stations appear many times in the data set, we estimate clustered standard errors (where the clustering is at the station level).

coefficients on the demographic variables change significantly when comparing 1997 and 1998 or 1999. Whether this is the result of measurement error (these variable come from the 2000 census and correspond to conditions in 1999), or a change in the pricing function is unclear. Second, the estimated brand coefficients for those stations which make up a large share of our sample, Mobil, Crown, Shell and Texaco, vary from year to year. Third, in none of the years does there appear to be a consistent relationship between price and either station characteristics or localized competition. This finding is unlikely an artifact of the specific functional form used to measure competition or station characteristics. We have examined many specifications of localized competition, including the number of stores within 1/2 mile, 1 mile, 3 miles, and interactions of these measures, and found similar results. Similarly, we have examined many other station attributes (including measures of nearby traffic conditions) and found no effect using this sample of gas stations.

As noted above, Crown stations played a very different pricing strategy during our sample period than other station in Northern Virginia. In particular, Crown stations tended to charge relatively low prices independent of the localized competitive environment. For this reason, we fully interacted a Crown indicator variable with all of the other variables in the pricing equation – effectively dropping the Crown stations from the sample. The results for the non-Crown coefficients appear in Table 4.

The key difference we see in estimating the model for the non-Crown stations is the importance of the competition variables. The distance to the closest station is now both economically and statistically significant. For example, a station having a rival located next door is estimated to charge a price 1.4 cents lower than a station whose nearest rival is a mile away. While this finding causes our results to look more similar to the literature, it also suggests that the pricing function implied by equation (3) is not uniform across stations.

3.4 Many Stations Change Their Pricing Strategy Over Time

The persistence in pricing we see in Figure 5, after controlling for both time and station fixed-effects, suggests that stations may change their pricing behavior over time; i.e., a station changes its average relative price over time. To examine this we estimate a slightly modified version of equation (2) where we allow the station effects to vary by calendar year (k=1997, 1998, 1999):

$$\text{(4)} \quad \mathrm{p}_{it} = \sum_{t} \gamma_t (\text{Week Indicators}_t) + \sum_{i,k} \theta_{ik} (\text{Station Indicators}_i)(\text{Year}_k) + e_{it}$$

If a station's idiosyncratic relative pricing changes from year to year ($\theta_{i,1997} \neq \theta_{i,1998} \neq \theta_{i,1999}$), we conclude that the station is pursuing a systematically different pricing strategy from year to year. We use two different approaches to measure how much a station's idiosyncratic pricing changes from year to year.

First, we record the percentile corresponding to a station's estimated fixed-effect in the store-effect distribution in year k; i.e., we rank all $\theta_{i,k}$ from smallest to largest and record the percentile corresponding to each $\theta_{i,k}$. We then calculate the difference in a station's percentile between each of the three years in our data set (1997 vs. 1998, 1998 vs. 1999, and 1997 vs. 1999).[24] These results are shown in Table 5. The table shows that small changes in a station's relative pricing are fairly common. For example, between 1997 and 1998 more than half of gasoline stations change their relative position in the pricing distribution by at least 10 percentile points. Further, while less frequent, some stations dramatically change their position in the pricing distribution, e.g., between 1997 and 1998 4% of gasoline stations estimated store-effects changed by more than 50 percentile points in the pricing distribution.

Second, we measure the absolute change (in cents) in the station effects from year to year. In Table 5, we see that many of the changes in station effects are statistically significant. In comparing stores observed in 1997 and 1998, 1997 and 1999, and 1998 and 1999, we find that 33%, 45%, and 27% (respectively) of changes in estimated store effects are statistically significant with a (conditional) mean change in price between 3 and 4 cents. The observed changes in pricing strategy are economically important. For example, in our data, the mean margin stations earn is roughly 14 cents per gallon.

4.0 Existing Models of Retail Pricing

Our empirical results are of limited use in isolation from a model of firm behavior. In this regard we suffer somewhat from an embarrassment of riches -- many models of pricing appear relevant to retail gasoline. Because there are so many, we use this section to

[24] In estimating equation 4 we require at least 10 observations per year. Thus, not all stations appear in all years. With this restriction we were limited to examining 170, 163, and 193 comparisons between 1997 and 1998, 1997 and 1999, and 1998 and 1999 respectively.

first relate these models and their empirical predictions to one another and defer to the next section relating those predictions to our results.

We are aware of five different types of models of pricing behavior that may be applied to retail gasoline. The first set of models assume that each retailer's actions in each period are independent of prior play. In pure strategies, these models predict that in each period retailers will charge the single-period profit-maximizing prices which will vary with localized demand, competition, and marginal costs. An important implication is these models predict no inter-temporal price variation when costs and market structure remain constant. Manuszak (2002) and Thomadsen (2005) are typical examples of this modeling approach. Although the model's complexity prohibits one from making definitive statements about its predictions for margins, in practice, Manuszak finds that his model generates roughly constant markups over time when demand follows a mixed logit.[25]

A second set of models allow for mixed strategies, and thus generate equilibria in which prices and margins vary even when costs and market structure remain constant. Varian (1980) provides an explanation of why a retailer would vary retail prices, independent of changes in wholesale prices that appears appropriate for gasoline retailing.[26] In Varian's model, consumers are heterogeneous in their willingness to search for low prices; some buy only at the first retailer they encounter, others compare prices and buy from the retailer offering the lowest price. Consequently, each retailer faces a tradeoff between charging a high price and selling only to consumers who do not search, versus charging a low price and potentially also selling to consumers who do search. Varian shows that the only symmetric equilibrium features mixed strategies, where all retailers choose their price from a continuous distribution with no mass points. In this equilibrium each retailer changes his price each period.

Other models formulate competition as a repeated (history-dependent) game and are thus also able to generate equilibria in which prices and margins vary even when costs and

[25] See, for example, Manuszak's Figure 4.

[26] There are other models of retailing which generate changes in retail prices independent of costs. Conlisk et al. (1984), Sobel (1984) and Pesendorfer (2002) examine how changes in retail prices can be used as a means of price discrimination. These models require that purchases can be shifted over time (either by consumers waiting to purchase or carrying inventory for future consumption), and are thus not relevant for gasoline retailing. Pashigian (1988) and Pashigian and Bowen (1991) develop models which predict that prices for goods with a "fashion" element should systematically decline over a fashion season independent of wholesale costs as retailers learn which styles are popular with consumers.

market structure remain constant. These dynamic models can be grouped into three subcategories: (1) models of collusive behavior, (2) models with history-dependent demand curves, and (3) models of Edgeworth cycles.

A number of papers use collusive equilibria with price wars to explain changes in margins over time. Green and Porter (1984) provide a model of collusive behavior that relies on imperfect monitoring to generate periodic price wars in equilibrium. Although they explicitly model competition in industries characterized by quantity competition, commonly known cost functions, and imperfect monitoring, their model can be extended to cover industries with price competition where the uncertainty is over the cost functions rather than the price. For example, Athey and Bagwell (2001) and Athey et al. (2004) model an infinitely repeated Bertrand game with publicly observed prices and private i.i.d. cost shocks, which closely matches many of the features of retail gasoline competition. Applying a semi-parametric approach to examine stations' pricing behavior directly, Slade (1987, 1992) finds evidence of a price war in Vancouver, Canada in 1983. She finds that stations' pricing behavior – in particular, stations' responses to their competitors' prices – varies over time.

Rotemberg and Saloner (1986) also offer a model of collusion that predicts fluctuating margins. In their model collusion breaks down during periods of relatively high demand, due to the fact that during those periods, the gains from cheating are more likely to outweigh the subsequent punishments during lower demand periods. Nevertheless, this model does not appear particularly applicable to our data since the periods[27] in our data are very short (perhaps less than one day) relative to the speed of changes in demand

A second group of dynamic models stems from the extensive recent empirical gasoline pricing literature focusing on the asymmetric adjustment of the retail price of gasoline to changes in wholesale price. Lewis (2005a) provides theoretical underpinnings for these findings by formulating a "reference price" model that leads consumers to search less when prices are falling. In his model, consumers are slow to update their expectations about the distribution of prices and thus search less than they should when prices are falling. This generates a kinked residual demand curve which in turn leads to asymmetric effects of marginal cost shocks on retail prices.

[27] Porter (1985) defines a time period as "the length of time it takes rivals to learn of the [cheating] and the additional time it takes them to cut their prices in response."

A third group of dynamic models that speak to our data stem from a model proposed by Maskin and Tirole (1988). In these models, stations play an alternating-move game choosing prices from a discrete grid. In equilibrium, stations undercut one another on price until it becomes unprofitable, at which point stations begin a new cycle by charging a high price. Although the original theoretical model relies on a number of assumptions inconsistent with retail gasoline competition, Noel (2005) has shown that cycling equilibria are still possible under considerably weaker conditions. Eckert (2002, 2003) and Eckert and West (2003, 2004a, 2004b) find evidence consistent with Edgeworth cycles in several Canadian cities, as does Noel (2007a , 2007b). One shortcoming of these models is that it can be difficult to determine when and whether stations are in a cycling equilibrium. Eckert (2002) and Noel (2005) use a Markov switching regression to determine this.

5.0 Evaluating theories of retail pricing for gasoline markets

The models described in the previous section have general predictions about the distribution of retail prices. In this section of the paper we describe how well each model matches our empirical findings. While no one theory can be expected to fully characterize the market place, we find substantial shortcomings in each approach.

5.1 Static Games with Pure Strategies

Modeling gasoline stations as charging a fixed markup over cost; i.e., modeling a station's decision using pure strategies as in Manuszak (2002) and Thomadsen (2005), has some empirical support. Our findings suggest that a large fraction of the retail gasoline price variation can be explained by including time effects, which control for common wholesale price changes, and station effects, which non-parametrically control for station specific localized demand, competition, and costs. In particular, the use of time-invariant store effects explains most of the large differences between a station's price and the market price. This can be seen by comparing the residual plots from Figures 2 (which only controls for time effects) and Figure 4 (which also controls for station effects). The evidence strongly suggests that gasoline stations have systematically different mean prices.

We see two key weaknesses of using the fixed mark-up approach in our data. First, prices change substantially from period to period suggesting that a fixed markup model is potentially missing important aspects of a gasoline station's pricing behavior. This can most clearly be seen by examining the plot of the Markov Transition Matrix in Figure 5. This graph shows us that even controlling for the systematic component of a station's pricing, there is still a substantial probability that the station will be charging a different relative price in subsequent periods. Further, the matrix shows that the movement back to mean pricing takes many periods. For example, if a station is charging a price 5 cents less than its mean price (an event that occurs 10% of the time) the probability it will charge a price within a penny of its mean price in the next period is only 2%. Clearly, there are dynamic components to pricing.

Second, while there is a systematic aspect of a station's pricing, a significant fraction of stations appear to change where they are in the pricing distribution from year to year. The fraction changing price is relatively large, nearly 30%, and the changes in a stations position in the price distribution can be substantial. Why stations change their pricing behavior (choosing a new mean price) is unclear to us. However, the fact that station's choose to change their pricing decision relative to their rivals for unobservable reasons limits the ability of this modeling approach to provide good predictions of what retail prices should look like.

Finally, even though there are systematic differences in mean pricing across stations, implementation of the modeling approach may be difficult because of data limitations. In our data, only a station's brand affiliation and measures of localized demand (zip-code level demographics) explain a sizeable fraction of a station's systematic mark up. The failure of either station amenities or measures of localized competition to explain station markups is disappointing. To credibly identify these types of models, the econometrician must observe characteristics of stations that both vary across stations and are associated with price. Equally troubling is that some brands behave very differently than others for unknown reasons. Crown gas stations were low price leaders in the Northern Virginia suburbs. As Figure 6 demonstrates, Crown systematically tried to be the lowest priced gas station relative to its rivals. To our knowledge there is no set of variables that would allow us to *a priori* predict this behavior.

5.2 Static Games with Mixed Strategies

Some aspects of gasoline pricing are consistent with prices being generated by mixed strategy similar to Varian (1980). We find that the modal choice for a gasoline station is to change its price each week. This is consistent with Varian's model which has no mass-points.

Strictly speaking, all firms in Varian's model should have the same mean price (retailers in Varian's model are identical and thus draw prices from the same distribution). However, it would not be difficult to build some heterogeneity into the model, e.g., allow station's to face either different numbers of competitors or different fractions of consumers who search, to generate different pricing distributions for different gas stations.

The main drawback we see from Varian's model is that while prices change every period, each price draw should come from the same pricing distribution. Empirically, this result is clearly violated. Figure 5, for example, shows that the price distribution for time t+1 depends importantly on the price at time t. The modal price at time t+1 is the price at time t, and the pricing distribution at time t+1 is tightly centered around the price at time t. While this result could be explained by assuming that gasoline stations experience idiosyncratic autoregressive cost shocks, we find this explanation unlikely. Instead, it appears that a model of true dynamics; i.e., recent history matters, is required to explain changes in a gasoline's relative margin over time.

5.3 Repeated Games with Collusion

The models of tacit collusion model with periodic price wars, e.g., Green and Porter, predict substantial changes in margins over time. While we see dramatic changes in margins in Northern Virginia, other aspects of the pricing distribution do not support tacit collusion of the type seen in these models. There is substantial variation in the margins earned by gasoline stations at a point in time (see the plot of the 25th, 50th, and 75th percentiles of the pricing distribution in Figure 1). Clearly, substantial variation in margins among participants within a market at a point in time undermines the ability of a cartel to operate. Moreover, as discussed at length, in every time period, including periods of high and low margins, we observe firms changing their relative position in the pricing distribution.[28] The mechanism that supports collusion in these models is that decreases in prices by one firm are met by decreases in price for all firms. If a significant fraction of firms are changing their relative price every period, it is unclear why the market is not always in the penalty phase.

[28] We have recalculated the transition matrix shown in Figure 5 separately by year and find the same pattern. Gasoline stations are more likely than not to change their prices every period in each year.

5.4 Asymmetric Adjustment

In order to examine asymmetric adjustment as an explanation for our data, we follow Borenstein et al. (1997) and Bachmeier and Griffin (2003) and Lewis (2005a), in estimating the following equation:

$$(5)\ \ \Delta\text{RET}_t = \sum_{k=0}^{2}\left(\beta_k \Delta\text{RACK}_{t\text{-}k} + \beta_i^+ \Delta\text{RACK}_{t\text{-}i}^+\right) + \sum_{k=1}^{2}\left(\theta_k \Delta\text{RET}_{t\text{-}k} + \theta_k^+ \Delta\text{RET}_{t\text{-}k}^+\right)$$

$$+\alpha_0(\text{Time Trend}_t) + [\delta_0 + \delta_1\text{RET}_{t\text{-}1} + \delta_2\text{RACK}_{t\text{-}1}] + \varepsilon_t$$

where:

$\Delta\text{RET}_t = \text{RET}_t - \text{RET}_{t\text{-}1}$, $\Delta\text{RACK}_t = \text{RACK}_t - \text{RACK}_{t\text{-}1}$, $\Delta\text{RACK}_t^+ = \max\{\Delta\text{RACK}_t, 0\}$, and and $\Delta\text{RET}_t^+ = \max\{\Delta\text{RET}_t, 0\}$.

In equation (5) the coefficients with the + superscript correspond to the asymmetric price adjustment terms; i.e., interactions between the change in rack or retail price and an indicator variable corresponding to a price increase. Note that the specification allows retail prices to adjust asymmetrically in response to both changes in wholesale (rack) and lagged retail prices changes. The term in brackets is defined as the error correction component of the estimating equation which implicitly defines the long run relationship between retail and rack prices.

There is some controversy as to how to correctly estimate equation (5). Borenstein et al. estimate all of the parameters from equation (5) in one step. Bachmeier and Griffin (B&G) argue that a two step procedure is preferred. In their preferred approach the error correction term is estimated in a first stage. The estimated coefficients from the first stage are then imposed on the model (as if estimated without error) and the remaining parameters are estimated in the second stage. We estimated models of asymmetric price adjustment using the estimation techniques very similar to both Borenstein[29] et al. and B&G,[30] shown in

[29]In contrast to Borenstein et al., we do not instrument for upstream prices. In our data, the upstream price is the price of wholesale gasoline at the Fairfax rack. Refiners supplying wholesale gasoline in Fairfax use a pipeline that connects the major U.S. refining region in Texas and Louisiana to the major population centers in the eastern U.S. (including most of the states of Virginia, Maryland, New Jersey and metropolitan New York City). Thus, refiners supplying Fairfax have the option of selling gasoline anywhere along the pipeline (and possibly shipping the gasoline via other pipeline to other regions of the U.S.). Because gasoline demand in Northern Virginia is such a small fraction of U.S. gasoline demand, we treat the rack price as unaffected by demand in Northern Virginia.

[30] Following their suggestion, we estimate B&G's model by first estimating the cointegrating relationship (corresponding to the error correction term) using OLS. We use these parameter estimates to construct the error correction term. We then estimate equation (6) by OLS and calculate Newey-West standard errors.

columns 1 and 2, respectively, of Table 6.[31] Because the models are estimated using significantly different techniques, only the coefficients corresponding to the price adjustment terms shown in Table 6 are directly comparable.[32]

The parameter estimates corresponding to the price adjustment terms (the $\Delta\text{Rack}_{\text{t-k}}$ and $\Delta\text{Ret}_{\text{t-k}}$ terms) using the two estimation approaches are remarkably similar both in terms of the magnitude and degree of statistical precision. The estimated coefficients, however, are not economically plausible or similar to the results of either Borenstein et al. or B&G. For example, our estimates imply that wholesale price increases, *but not price decreases*, are passed through to retail. The estimated coefficient on the contemporaneous increase in wholesale price ($\Delta\text{RACK}_{t}^{+}$) is estimated to be between .25 and .29, and is statistically significant. The estimated effect on a contemporaneous wholesale price decrease is never economically or statistically significant (less than .03 in absolute value). In contrast, Borenstein et al. and B&G find much larger estimates of the contemporaneous effect of changes in wholesale prices on retail prices for both wholesale price increases and price decreases.[33] For this reason, we do not think a model of asymmetric price adjustment provides a good explanation for the changes in retail mergers we find in our data.

The last two columns of Table 6 include indicator variables corresponding to the years 1997 and 1998. For the B&G model we include these variables in the estimation of the cointegrating relationship, in Borenstein et al. we simply add them to equation (5). If these variables are economically significant, the implication is that the long-run margin is shifting between years. The estimates of B&G model suggest that the margins have changed. Here we see that long-run margins appear to shift down in both 1998 and 1999 relative to 1997. We interpret this evidence as suggesting that city-level margins appear to change by economically significant amounts over time.

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[31] Because we only have 3 years of weekly data for one city, it is not possible to include time dummies in our model as B&G and Borenstein et al. do. We have, however, included month dummies to control for seasonality in estimating equation (6). These coefficient estimates are not included for brevity, but are available on request from the authors.

[32] While both techniques estimate the same model, a non-linear transformation is required to directly compare the parameter estimates corresponding to the intercept and the error correction terms of the two models.

[33] In all of the specifications B&G estimate, the contemporaneous effect of a change in upstream price on the downstream price is at least .75 (see Table 1, page 774). Borenstein et al., find large differences in the effect of contemporaneous wholesale price increases than decreases on retail prices, e.g., .62 vs. .2 in their Table 1, page 320, column 4. However, both papers find economically and statistically significant effects of decreases in wholesale price on retail price not seen in our data.

5.5 Edgeworth Cycles

The most widely used test for Edgeworth cycles to date appears to be the "eyeball test". The theoretical model predicts that retail stations' margins should have rapid increases followed by slower decreases as the stations undercut one another. This leads to a pronounced saw-tooth pattern over time, which is particularly noticeable when wholesale prices are roughly constant; most empirical tests of cycle behavior are constructed largely with the goal of quantifying this test. Eckert and West (2003) suggests several possibilities, including: looking for asymmetry in the distribution of the length of "price runs"[34] and looking at the number of periods with little or no change in retail price (or margin). Lewis (2007) uses a threshold for the median daily price change. Eckert (2002) and Noel (2005, 2007b) offer more complex models of regime-switching to identify cycling, but this approach necessitates additional modeling assumptions regarding the behavior of prices under each regime. Thus, a finding of regime switching cannot be distinguished from a failure to correctly model the within-regime pricing behavior of the stations.

We employ several tests and find that our data are largely inconsistent with cycling behavior. First, as can be seen in Figure 1, the characteristic saw-tooth pattern indicative of cycling is not readily apparent. While there are some short-term fluctuations in margins, these are all on the order of one to three cents and do not explain the larger fluctuations. The larger fluctuations appear to be too long-lived to be consistent with cycling. The existing literature has typically found cycles measured in hours or weeks, not months. Second, the Markov transition matrices in Figure 5 are not consistent with cycling behavior. The theory of cycling behavior (both symmetric and asymmetric) predicts that while stations might be relenting or undercutting, they would not leave their margins unchanged. Thus, there should be very little mass on the diagonal. This is not consistent with what we observe: that stations residuals are most likely to remain where they were in the previous week, and that there is very little mass in the upper left and lower right corners.

[34] Where a "price run" is defined as a set of weeks with consecutive same-sign price changes.

6.0 Discussion and Conclusion

We have examined weekly pricing over a three year period in the late 1990s using a sample of 272 stations in Northern Virginia. Our main finding is that gasoline stations do not appear to follow simple static pricing rules. Gasoline stations do not appear to charge constant margins, nor do they appear to simply maintain a relative position in the pricing distribution from period to period. We find that from week-to-week gas stations are more likely than not to change their relative position in the pricing distribution (measured relative to a regional price or rank among nearby stations). There is also heterogeneity in stations' pricing behavior over time. Stations that charge very high prices or very low prices in one week are much more likely to charge high or low prices in subsequent weeks than stations charging prices near the mean. There is also an interesting asymmetry in this behavior: low priced stations are much more likely to remain low priced than high priced stations are to remain high. While most week-to-week changes in pricing position are small, a significant number of stations make large changes in their pricing behavior over time. For example, 24% of stations change their relative position in the pricing distribution by more than 25 percentage points between 1998 and 1999.

Our second finding is that the distribution of retail gasoline prices has relatively thick tails. We did not have a strong prior for what the distribution of gasoline prices should look like. Some characteristics of retail gasoline markets suggest that prices should be very tightly distributed about the mean price at a point in time, e.g., gasoline is fairly homogeneous and search is facilitated by prices being prominently posted in front of gas stations and consumers being mobile (in cars) when shopping. Alternatively, the empirical literature suggested there were some aspects that differentiated gasoline stations, such as station attributes and localized competition. While the variance of prices changes somewhat from year to year, the pattern is the same: retail gasoline prices are characterized by a distribution with relatively thick tails.

We believe our most interesting finding is that retail margins change sizably over time. For example, for a six month period the implied retail mark-up (retail price less taxes and wholesale prices) is roughly 19 cents for 6 months and then falls to about 10 cents for 3 months. The evidence suggests that the entire distribution is shifting over time; i.e., not just the median or mean. In a market with little entry or exit, little non-geographic differentiation, where wholesale prices are easily observed (rack prices are essentially public information), and roughly common across firms (there is very little variation in rack prices at a point in time), and with inelastic demand, one would expect roughly constant retail margins. Instead we see large changes in retail margins over time. An alternative explanation of coordinated behavior, such as tacit collusion followed by periodic price wars, is also difficult to accept given the apparent low level of concentration at the retail level in Northern Virginia – there are roughly *25* different brands of retail gasoline in Northern Virginia.[35] This finding is worthy of further investigation. It is possible to interpret many of our results as adding to mounting evidence, e.g., Eckert and West (2003, 2004a, 2004b), Noel (2007a, 2007b) and Slade (1992), that localized retail gasoline competition appears to be characterized by regime shifts in pricing.

[35] Because most of the individual branded stations are operated by firms other than the refiner, this likely understates the number of independent price-setting agents. Most stations in our data are operated either by a lessee dealer (an individual who leases the station from the refiner) or a jobber (a gas station owned by the dealer who operates as a franchisee). In these cases, the lessee dealer or jobber sets the retail price, not the refiner.

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Table 1: Descriptive Statistics for OPIS Sample

Variable	Station-Weeks	Mean	Standard Deviation	Minimum	Maximum
Price (cents)	28443	111.47	11.33	72	146
Number of gas stations within 1.5 miles	28443	12.94	6.53	0	30
Distance to Closest Gas Station (miles)	28443	0.21	0.35	0	3.08
Number of Pumps	28443	7.63	2.77	0	16
Indicator Variables:					
Convenience Store	28443	4.89%			
Provides Repair Service	28443	62.93%			
Outdated Format	28443	24.53%			
Self Serve Only	28443	83.81%			
Lessee Dealer	28443	57.35%			
Jobber Owned	28443	7.49%			
Population in Zip Code	28443	30,388	12458	1377	62132
Population Density in Zip Code	28443	4,390	2787	63	12306
Median Family Income in Zip Code	28443	72,106	18083	37304	154817
Percentage of Sample From:					
1997		36.25%			
1998		31.77%			
1999		31.98%			

Table 2: Comparison of Brand Distribution In New Image Marketing Census and OPIS Sample

Brand	OPIS Sample Brand Percentages, Weighted By Observations in OPIS sample	OPIS Sample Station Counts
AMOCO	n/a	n/a
BLUE MAX	n/a	n/a
BP	0.61%	1.47%
CHEVRON	0.65%	2.21%
CITGO	10.09%	15.44%
COASTAL	0.05%	0.37%
CROWN	7.54%	5.88%
DIXIE		
EAGLE		
EXXON	0.18%	0.37%
GAS KING		
GETTY	0.69%	0.74%
GLOBAL		
HESS	0.73%	1.47%
JAC		
MERIT	0.24%	0.37%
MOBIL	27.75%	24.26%
NO BRAND		
QUARLES		
RACETRAC		
SHEETZ	0.26%	0.37%
SHELL	23.35%	21.32%
SUNOCO	5.19%	5.88%
TEXACO	22.33%	19.12%
WAWA		
XTRA FUELS	0.33%	0.74%

Table 3: Regress Retail Margin
(Retail Price less Branded Rack) on Station Characteristics And Time Indicators

	Pooled		**1997**		**1998**		**1999**	
Variable	**Beta**	Std Error	**Beta**	Std Error	**Beta**	Std Error	**Beta**	Std Error
Number of Stations with 1.5 miles	0.000	0.027	-0.036	0.020	0.018	0.038	0.026	0.037
Distance to Closet Station (miles)	0.357	0.657	0.996	0.463	0.020	0.848	-0.005	0.766
If Convenience Store	-0.798	0.689	-0.169	0.678	-0.234	0.821	-0.709	0.912
If Service Bays	0.584	0.385	0.370	0.285	0.837	0.516	0.894	0.523
If Outdated format	0.595	0.319	0.126	0.415	0.700	0.410	0.946	0.412
Number of Pumps	-0.035	0.074	-0.048	0.050	-0.070	0.102	-0.018	0.108
If Self Serve	0.333	0.367	0.148	0.464	1.010	0.524	0.215	0.525
If Lessee Dealer	-0.152	0.368	-0.050	0.333	-0.446	0.487	0.117	0.472
If Jobber Owned	-0.351	0.603	-1.097	0.712	-0.719	0.758	1.027	0.859
log of population in zip code	-1.880	0.451	-0.740	0.270	-2.400	0.569	-2.557	0.616
Log of population density in zip code	0.985	0.224	-0.042	0.171	1.368	0.336	2.042	0.378
Log of median income in zip code	2.497	0.580	0.537	0.536	3.173	0.837	4.480	0.881
Station indicators (Citgo Ommited Station)								
BP	4.168	1.594	3.178	1.039	4.265	3.449	7.648	2.072
Chevron	-2.717	1.019	-2.770	1.067	-5.604	0.870	-0.447	1.005
Coastal	-11.483	0.806	-12.132	0.832	n/a		n/a	
Crown	-3.590	0.548	-3.883	0.710	-4.351	0.788	-2.041	0.802
Getty	0.760	1.218	0.314	2.148	0.623	0.783	1.737	0.940
Hess	-3.353	0.773	-1.902	1.155	-4.878	0.844	-2.808	0.964
Kenyon	-0.404	0.700	n/a		-1.691	0.856	n/a	
Merit	-1.729	1.331	n/a		-4.308	0.921	-1.063	1.541
Mobil	0.668	0.543	1.797	0.690	-0.438	0.731	0.667	0.797
Sheetz	-6.825	1.056	n/a		-7.005	1.345	-6.581	1.382
Shell	1.178	0.527	1.536	0.709	0.245	0.710	1.800	0.809
Sunoco	-2.352	0.675	-1.522	0.754	-3.356	0.891	-2.432	1.059
Texaco	2.250	0.479	2.665	0.701	1.320	0.672	2.766	0.724
Xtra Fuels	-1.725	0.736	-0.858	0.707	-0.671	0.847	n/a	
Constant	33.829	7.936	52.645	7.502	35.893	11.648	8.907	12.725
Number of Observations	28,156		10,228		8,932		8,996	
R-squared	0.644		0.670		0.647		0.597	

Notes: Omitted Brand is Citgo, Clustered Standard Errors

Table 4: Regress Retail Margin (Retail Price less Branded Rack) on Station Characteristics Non-Crown Stations

	Pooled	se	**1997**	se	**1998**	se	**1999**	se
Number of Stations with 1.5 miles	-0.002	0.028	-0.040	0.021	0.018	0.040	0.025	0.039
Distance to Closet Station (miles)	1.446	0.510	1.595	0.523	1.453	0.781	1.257	0.619
If Convenience Store	-0.947	0.697	-0.238	0.677	-0.462	0.836	-0.878	0.893
If Service Bays	0.575	0.385	0.367	0.287	0.821	0.516	0.882	0.526
If Outdated format	0.449	0.304	0.054	0.407	0.496	0.391	0.765	0.406
Number of Pumps	-0.070	0.076	-0.063	0.053	-0.130	0.104	-0.060	0.112
If Self Serve	0.447	0.365	0.187	0.473	1.233	0.529	0.343	0.518
If Lessee Dealer	-0.119	0.375	-0.002	0.347	-0.442	0.496	0.151	0.485
If Jobber Owned	-0.494	0.609	-1.218	0.706	-0.804	0.773	0.970	0.896
log of population in zip code	-1.886	0.467	-0.749	0.279	-2.437	0.594	-2.519	0.632
Log of population density in zip code	0.965	0.233	-0.044	0.178	1.348	0.349	1.999	0.393
Log of median income in zip code	2.469	0.637	0.407	0.581	3.288	0.932	4.484	0.966
Station indicators (Citgo Ommited Station)								
BP	4.112	1.600	3.062	1.087	4.443	3.426	7.846	2.089
Chevron	-2.667	1.048	-2.696	1.082	-5.661	0.882	-0.300	0.998
Coastal	-11.608	0.824	-12.158	0.842	n/a		n/a	
Crown	n/a		n/a		n/a		n/a	
Getty	0.903	1.236	0.447	2.150	0.818	0.785	1.940	0.987
Hess	-3.217	0.778	-1.813	1.185	-4.665	0.842	-2.631	0.964
Kenyon	-0.278	0.711	n/a		-1.670	0.891	n/a	
Merit	-1.538	1.340	n/a		-4.028	0.924	-0.842	1.566
Mobil	0.643	0.552	1.766	0.693	-0.381	0.723	0.673	0.835
Sheetz	-6.380	1.080	n/a		-6.354	1.375	-6.197	1.404
Shell	1.177	0.532	1.504	0.719	0.330	0.694	1.841	0.847
Sunoco	-2.235	0.674	-1.481	0.764	-3.122	0.871	-2.259	1.077
Texaco	2.214	0.483	2.616	0.705	1.358	0.659	2.768	0.755
Xtra Fuels	-1.252	0.726	-0.596	0.687	0.006	0.875	n/a	
Constant	34.459	8.421	54.260	7.990	26.804	12.455	8.945	13.437
Number of Observations	26,154		9,453		8,291		8,410	
R-squared	0.630		0.632		0.634		0.590	

Notes: Omitted Brand is Citgo, Clustered Standard Errors

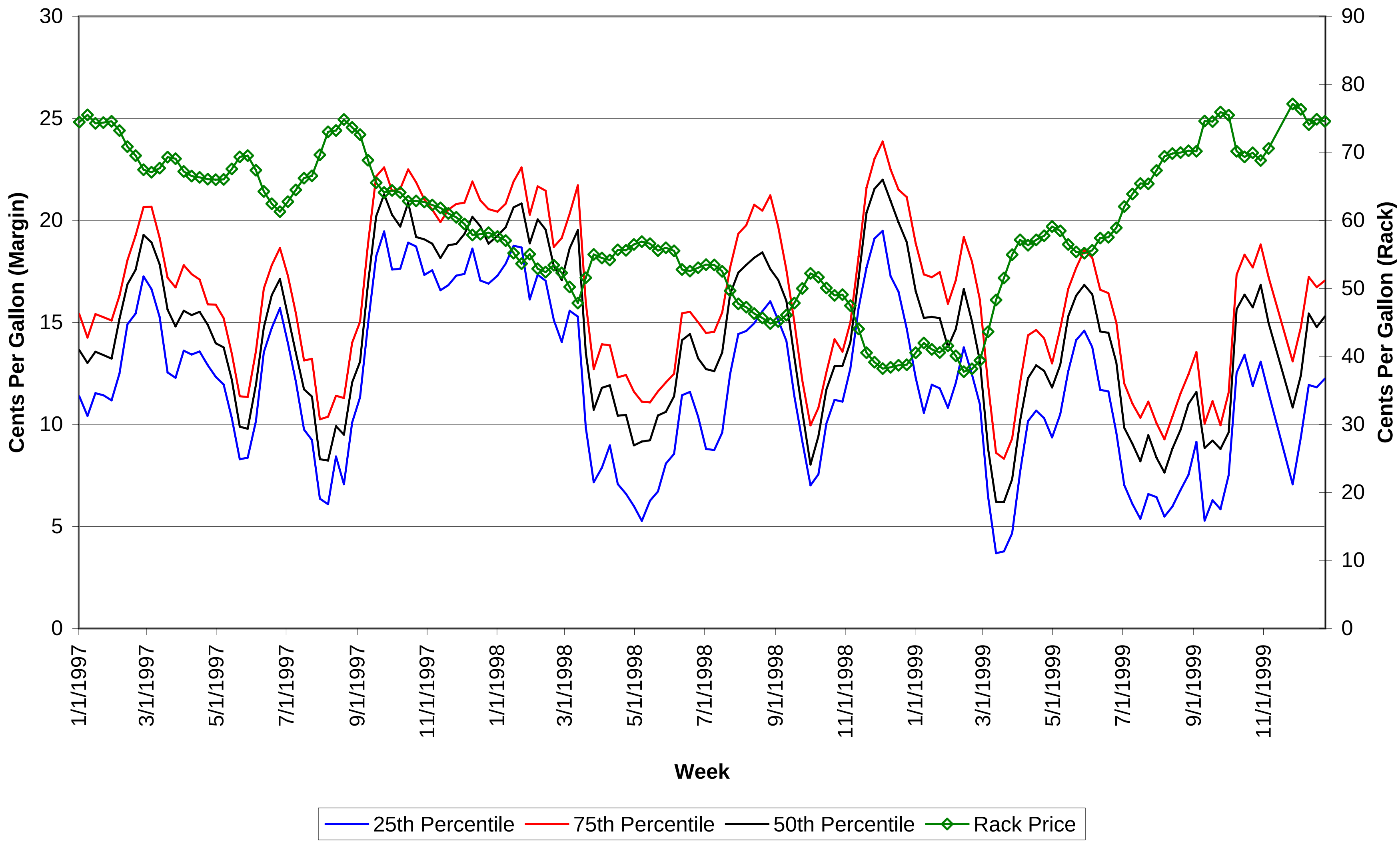
Table 5: Change In Relative Position of Gas Station Fixed Effects By Year

Change In Relative Position of at least:	**Between 1997 and 1998**	**Between 1997 and 1999**	**Between 1998 and 1999**
10 Percentage Points	51.76%	66.87%	35.23%
15 Percentage Points	37.06%	51.53%	20.73%
20 Percentage Points	24.71%	40.49%	13.47%
25 Percentage Points	16.47%	26.99%	9.84%
50 Percentage Points	4.12%	6.13%	2.07%
75 Percentage Points	0.59%	0.61%	0.52%
Changes that are Statistically Significant (T>2)	32.94%	44.79%	27.46%
(Conditional on being significant, in cents)	3.82	3.84	2.76
Number of Comparisions	170	163	193

Table 6: Estimation of Asymmetric Price Adjustment Models

	BCG		Bachmeier and Griffin		BCG		Bachmeier and Griffin	
	Coefficient	Standard Error	Coefficien	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Constant	3.898	1.264	-0.702	0.395	5.022	2.326	-0.679	0.372
$\Delta Rack_t$	-0.001	0.052	-0.031	0.041	-0.005	0.053	-0.030	0.041
$\Delta Rack_t$ *($\Delta Rack_t$ >0)	0.257	0.081	0.299	0.085	0.250	0.082	0.299	0.084
$\Delta Rack_{t-1}$	0.023	0.054	0.073	0.050	0.019	0.055	0.073	0.050
$\Delta Rack_{t-1}$ *($\Delta Rack_{t-1}$ >0)	0.142	0.081	0.176	0.101	0.138	0.082	0.177	0.101
$\Delta Rack_{t-2}$	-0.066	0.054	-0.016	0.038	-0.072	0.055	-0.016	0.038
$\Delta Rack_{t-2}$ *($\Delta Rack_{t-2}$ >0)	0.044	0.079	0.047	0.070	0.049	0.079	0.047	0.070
ΔRet_{t-1}	0.409	0.144	0.525	0.142	0.384	0.147	0.528	0.142
ΔRet_{t-1} *(ΔRet_{t-1} >0)	0.023	0.180	-0.110	0.253	0.041	0.181	-0.113	0.254
ΔRet_{t-2}	0.063	0.140	0.209	0.139	0.046	0.144	0.212	0.138
ΔRet_{t-2} *(ΔRet_{t-2} >0)	0.041	0.173	-0.088	0.231	0.051	0.176	-0.088	0.231
$Rack_{t-1}$	0.084	0.022	n/a	n/a	0.087	0.022	n/a	n/a
Ret_{t-1}	-0.081	0.022	n/a	n/a	-0.088	0.022	n/a	n/a
Time	-0.001	0.001	n/a	n/a	-0.010	0.034	n/a	n/a
Year Indicator:								
1998			n/a	n/a	0.317	1.784	n/a	n/a
1999			n/a	n/a	0.927	3.573	n/a	n/a
Error Correction Term	n/a	n/a	0.003	0.004	n/a	n/a	0.003	0.003
Cointegrating Relationship								
Constant	n/a	n/a	56.003	1.737	n/a	n/a	63.216	2.266
$Rack_{t-1}$	n/a	n/a	0.931	0.029	n/a	n/a	0.855	0.033
Year Indicator:								
1998	n/a	n/a			n/a	n/a	-3.409	0.855
1999	n/a	n/a			n/a	n/a	-4.856	0.699
Observations	151		151		151		151	
Estimation Method	OLS		OLS		OLS		OLS	

Figure 1: Weekly Retail Gasoline Margins and Branded Rack Prices 1997-1999



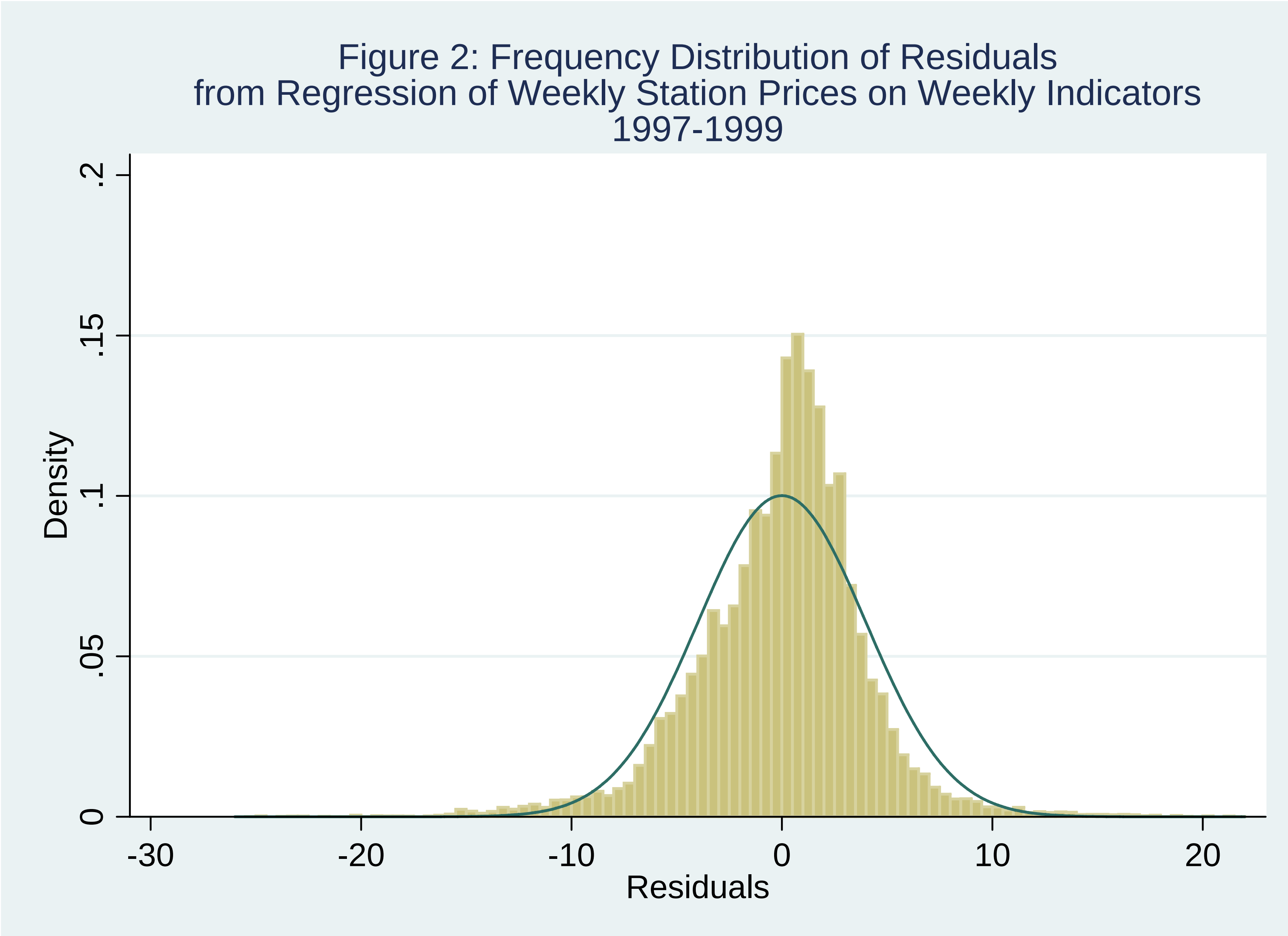


Figure 2: Frequency Distribution of Residuals
from Regression of Weekly Station Prices on Weekly Indicators
1997-1999
Density
0
.05
.1
.15
.2
-30
-20
-10
0
10
20
Residuals

Figure 3: Single-Period Empirical Markov Transition Matrix
(Residuals from Regression of Price on Week Indicators)

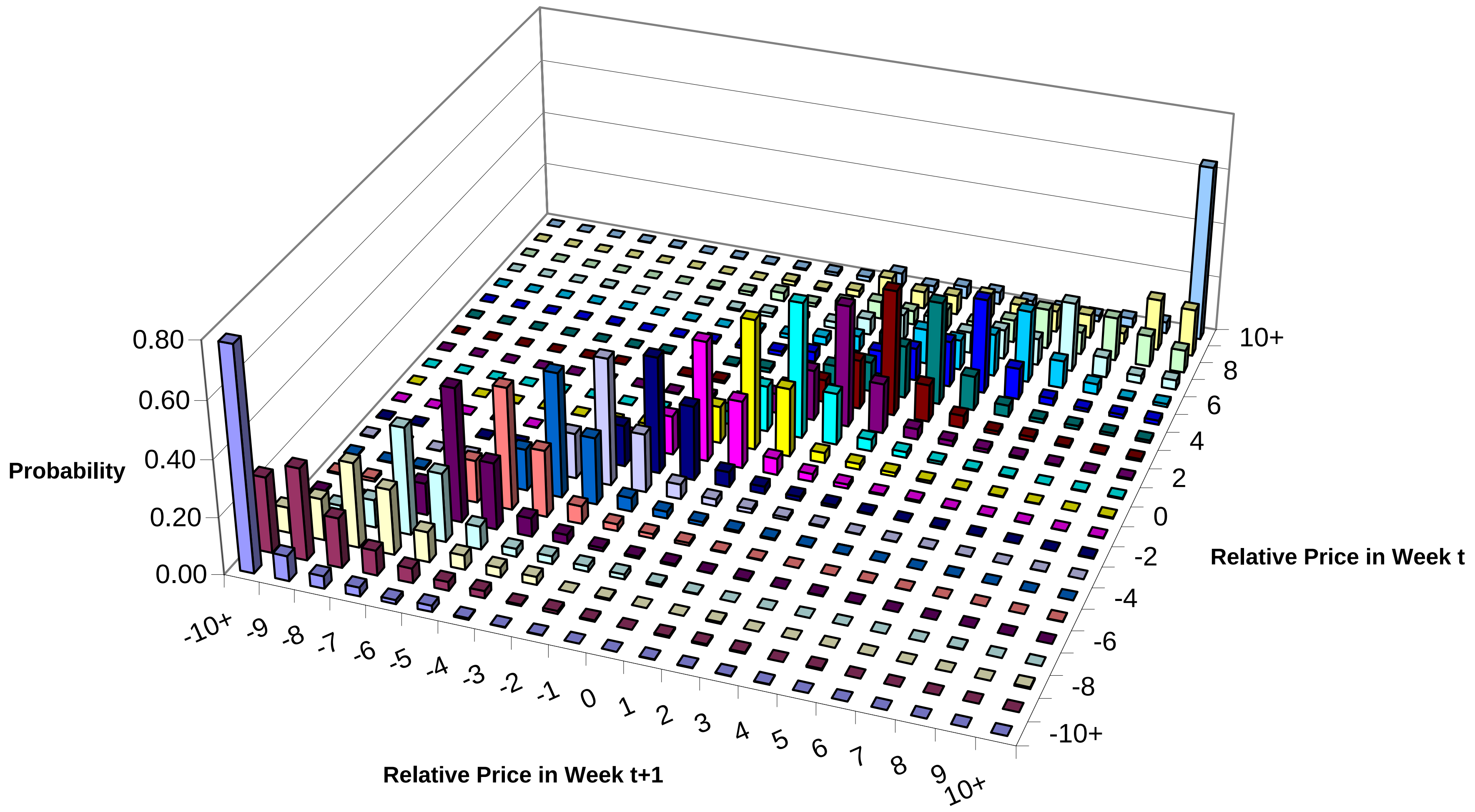


Figure 4: Frequency Distribution of Residuals
from Regression of Weekly Station Prices on Store and Weekly Indicators
1997-1999

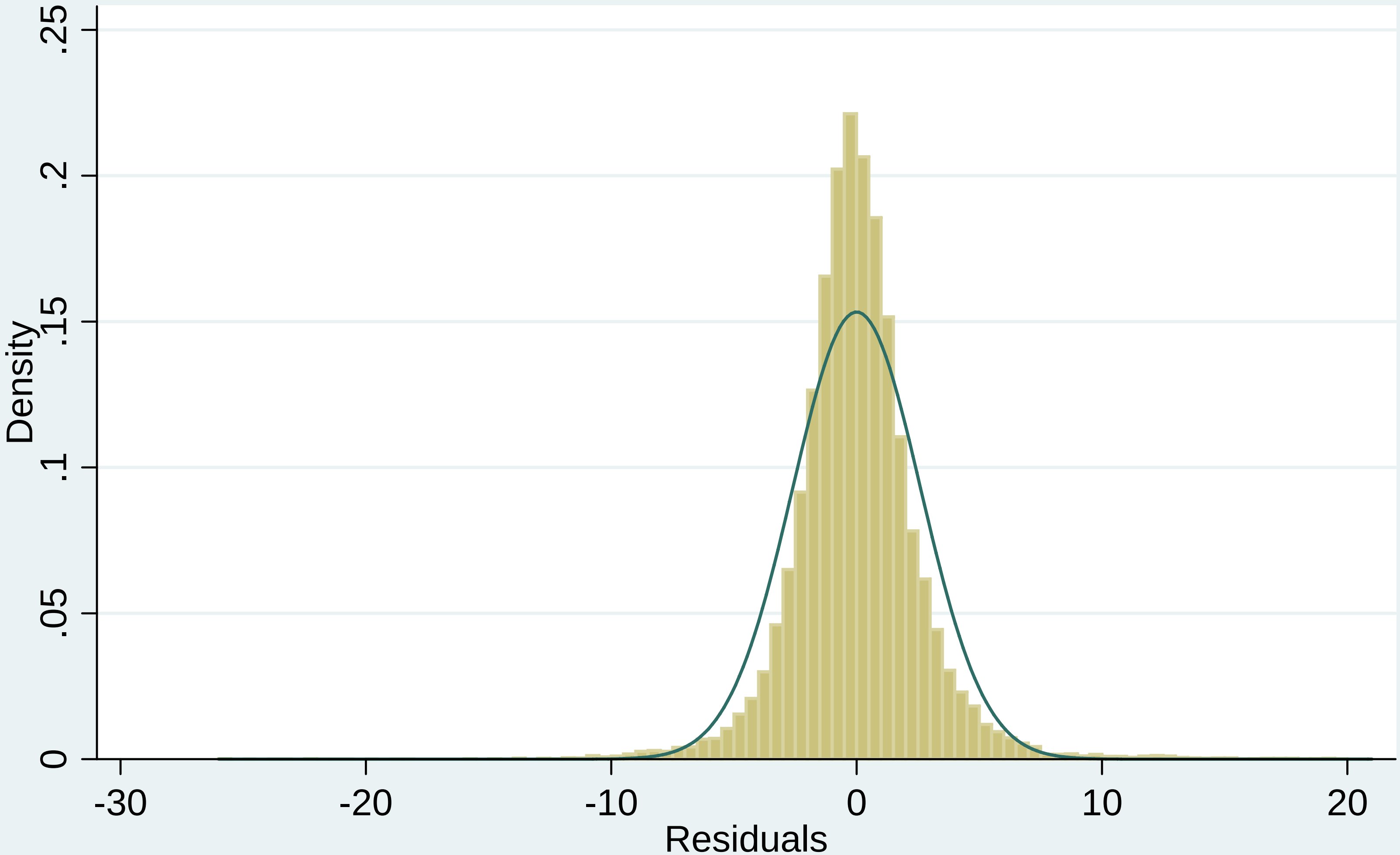


Figure 5: Single-Period Empirical Markov Transition Matrix
(Residuals from Regression of Price on Store and Week Indicators)

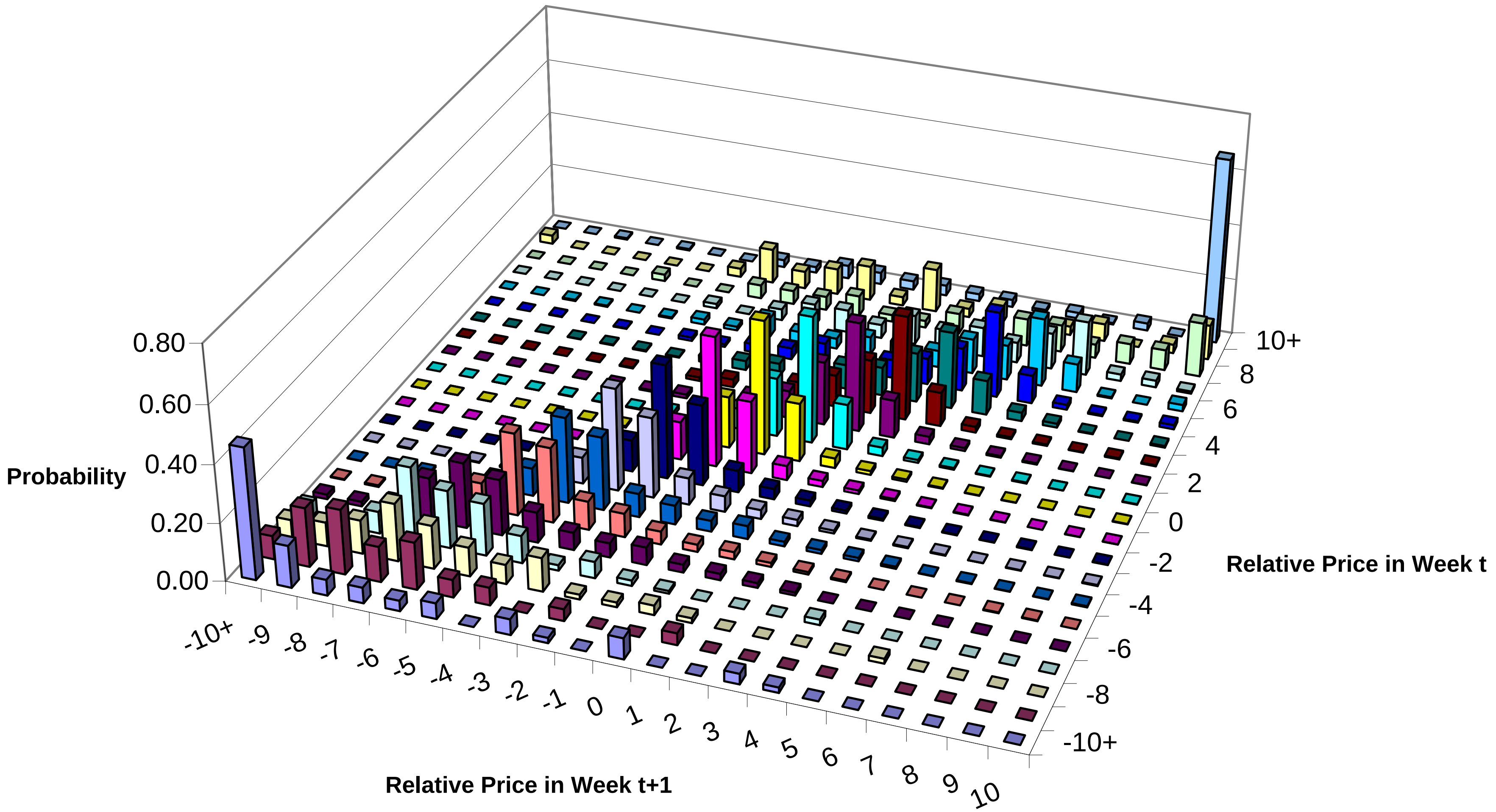
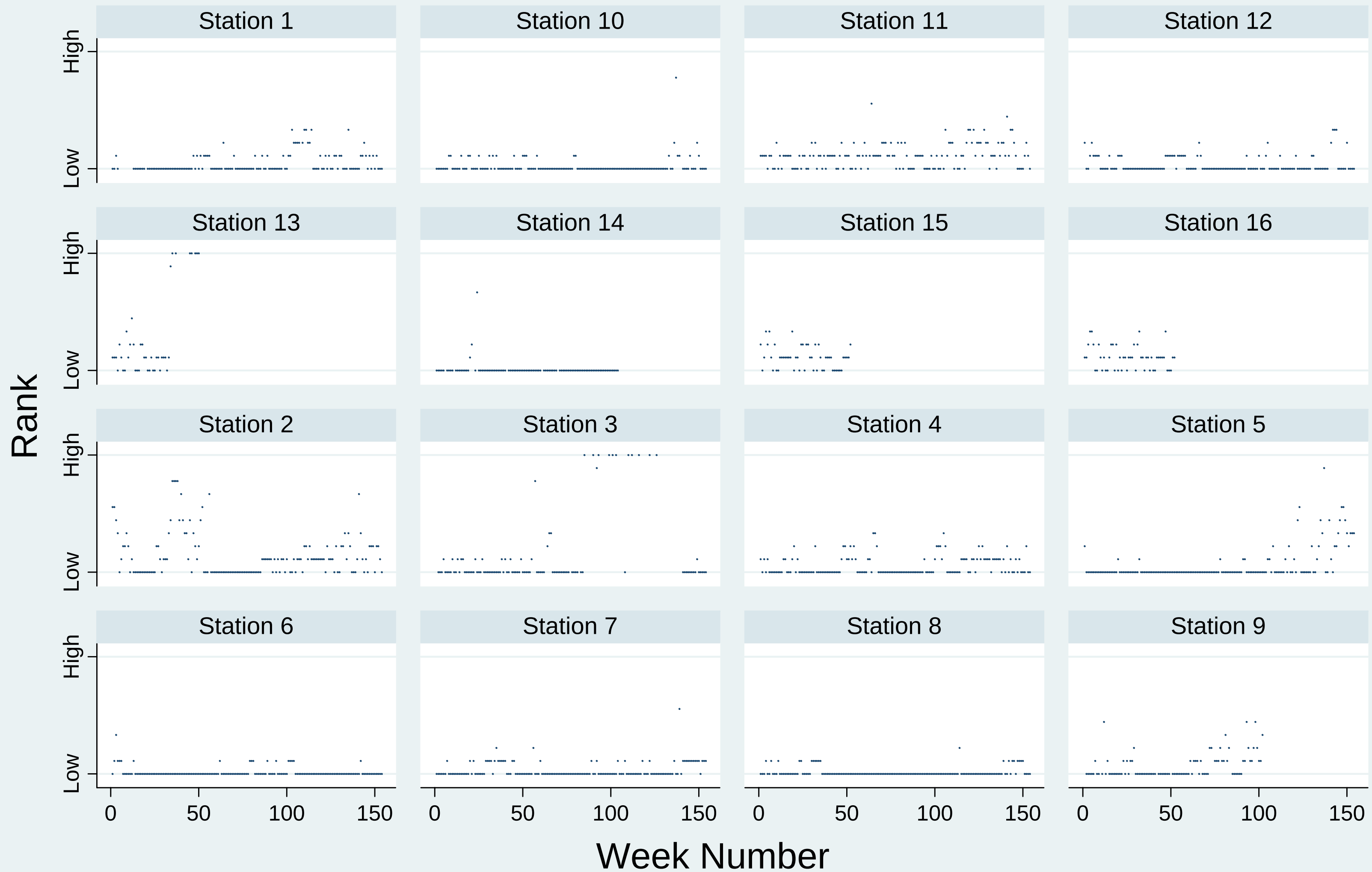


Figure 6: Rank of Crown Station Prices Relative to Nine Closest Stations



Graphs by Station

Figure 7: Markov Probabilities for Ten Closest Stations: Rank in Pricing Distribution at *t+1* conditional on Rank at *t*

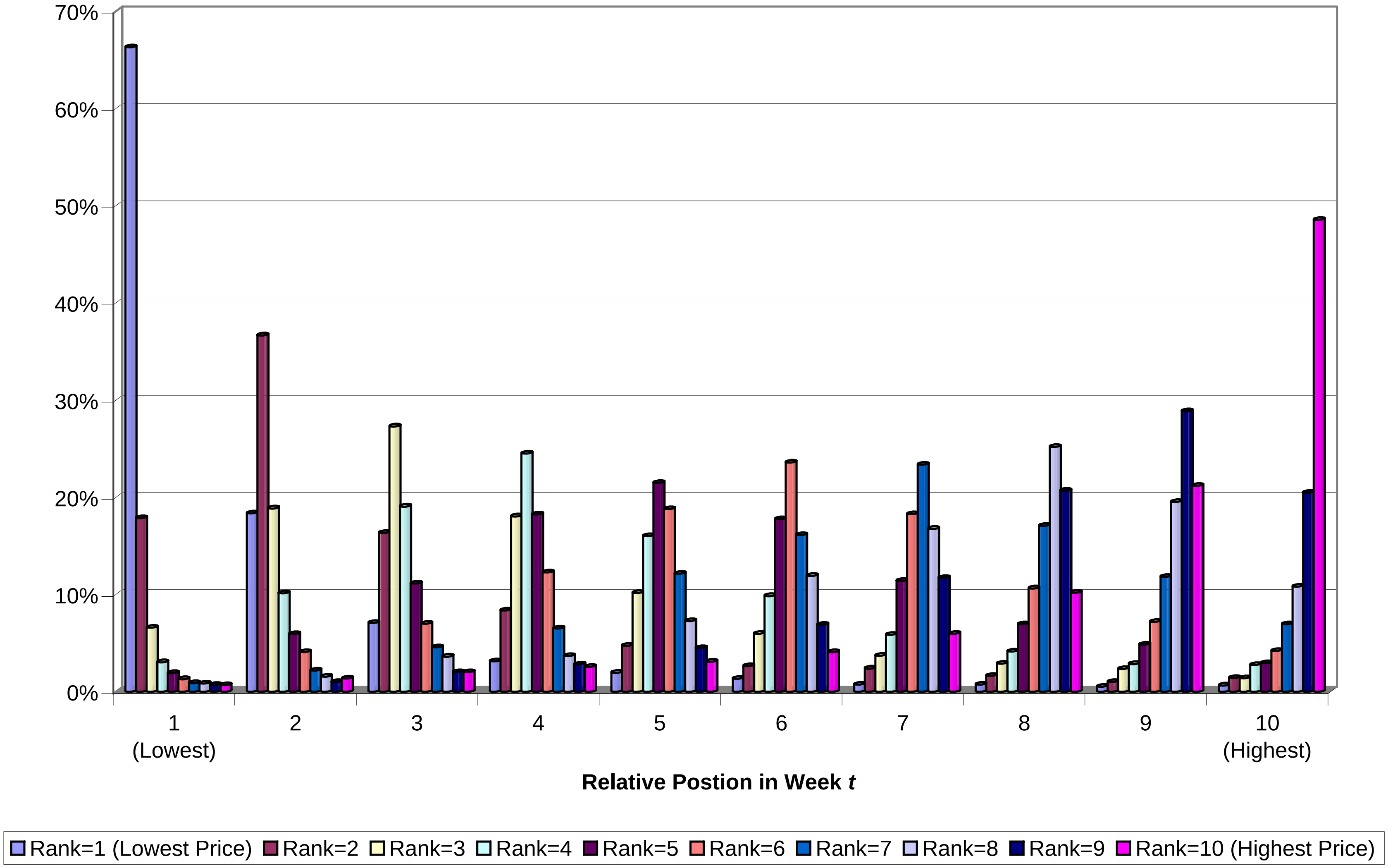
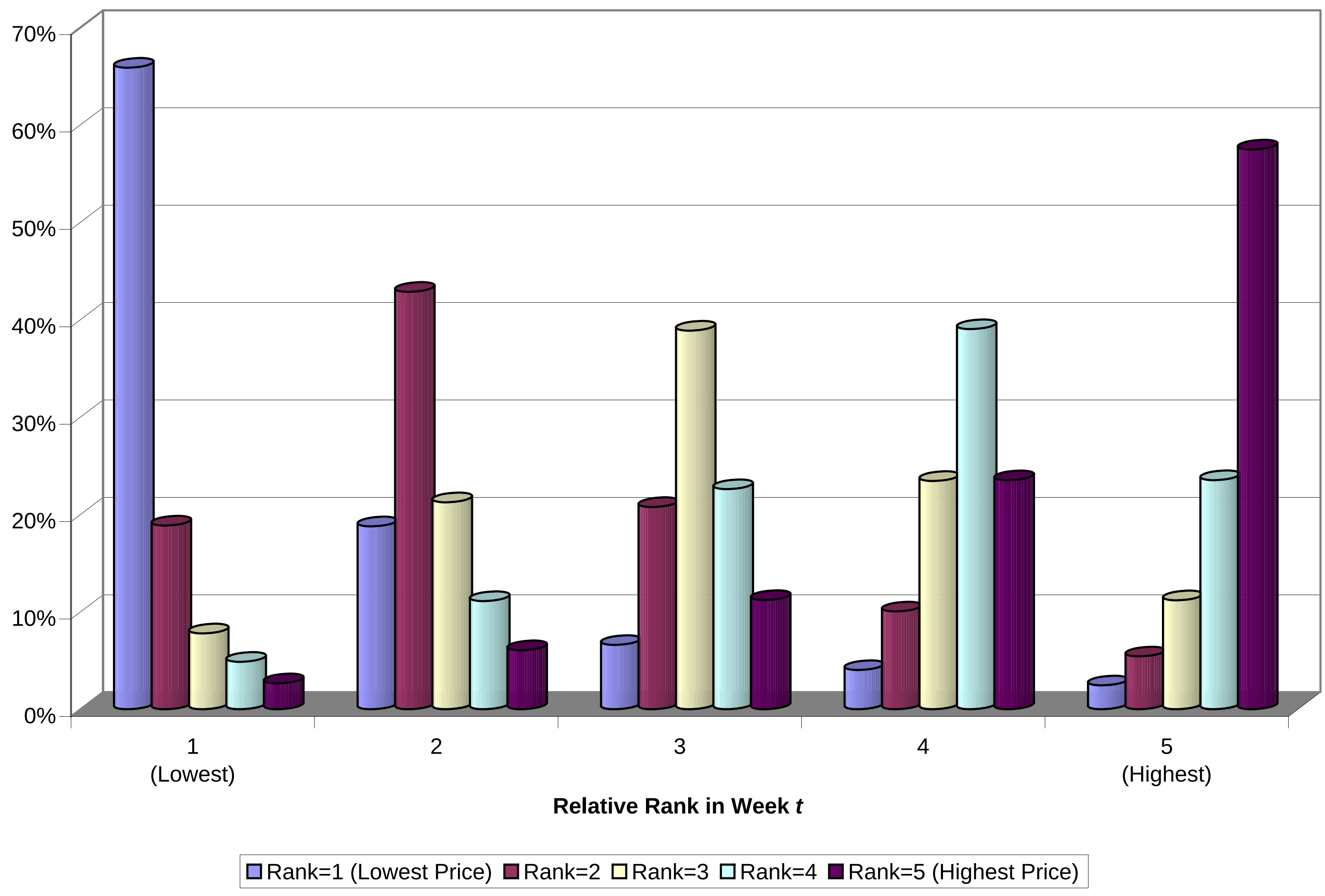


Figure 8: Markov Probabilities for Five Closest Stations:
Rank in Pricing Distribution at *t+1* conditional on Rank at *t*

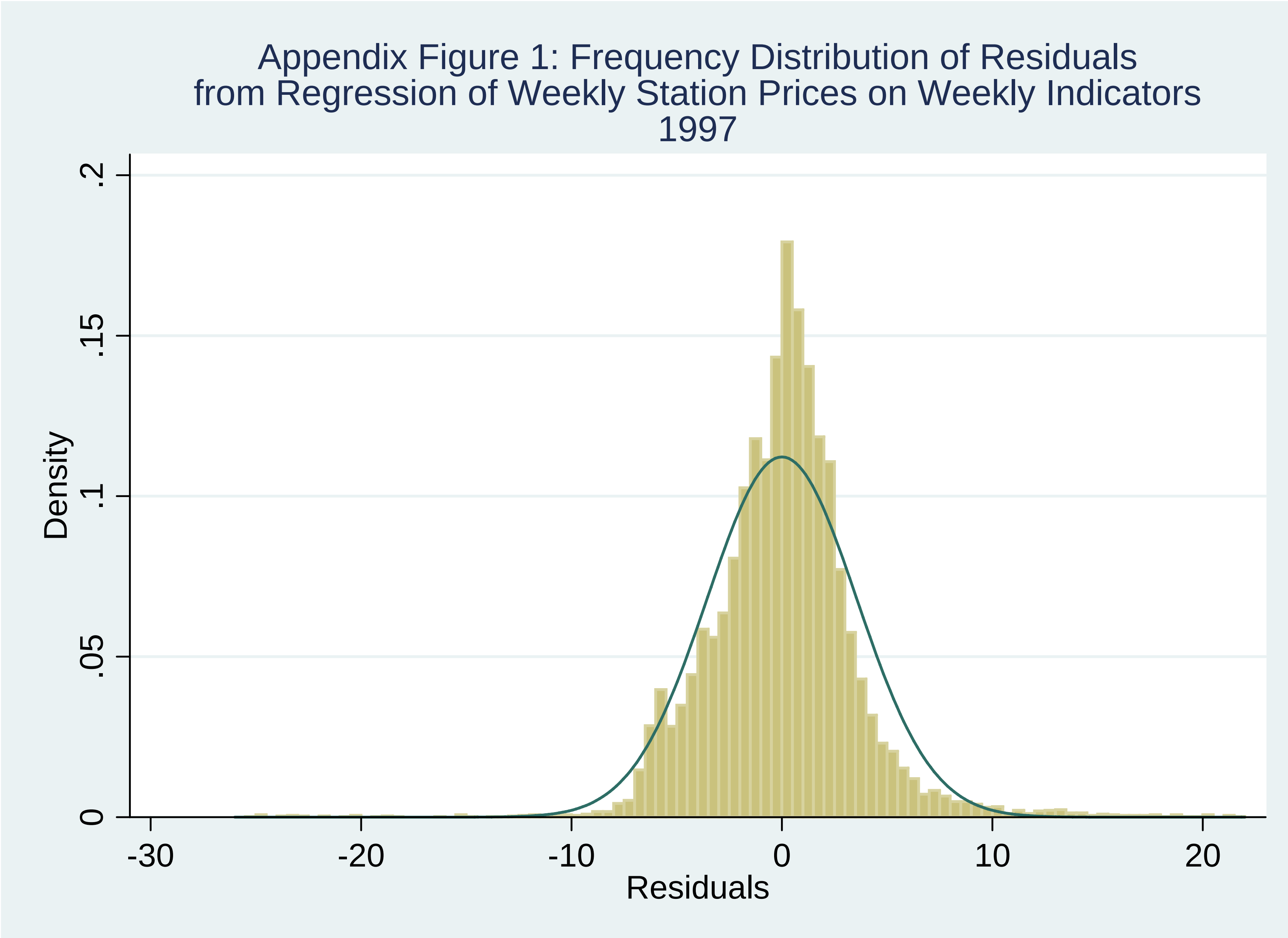


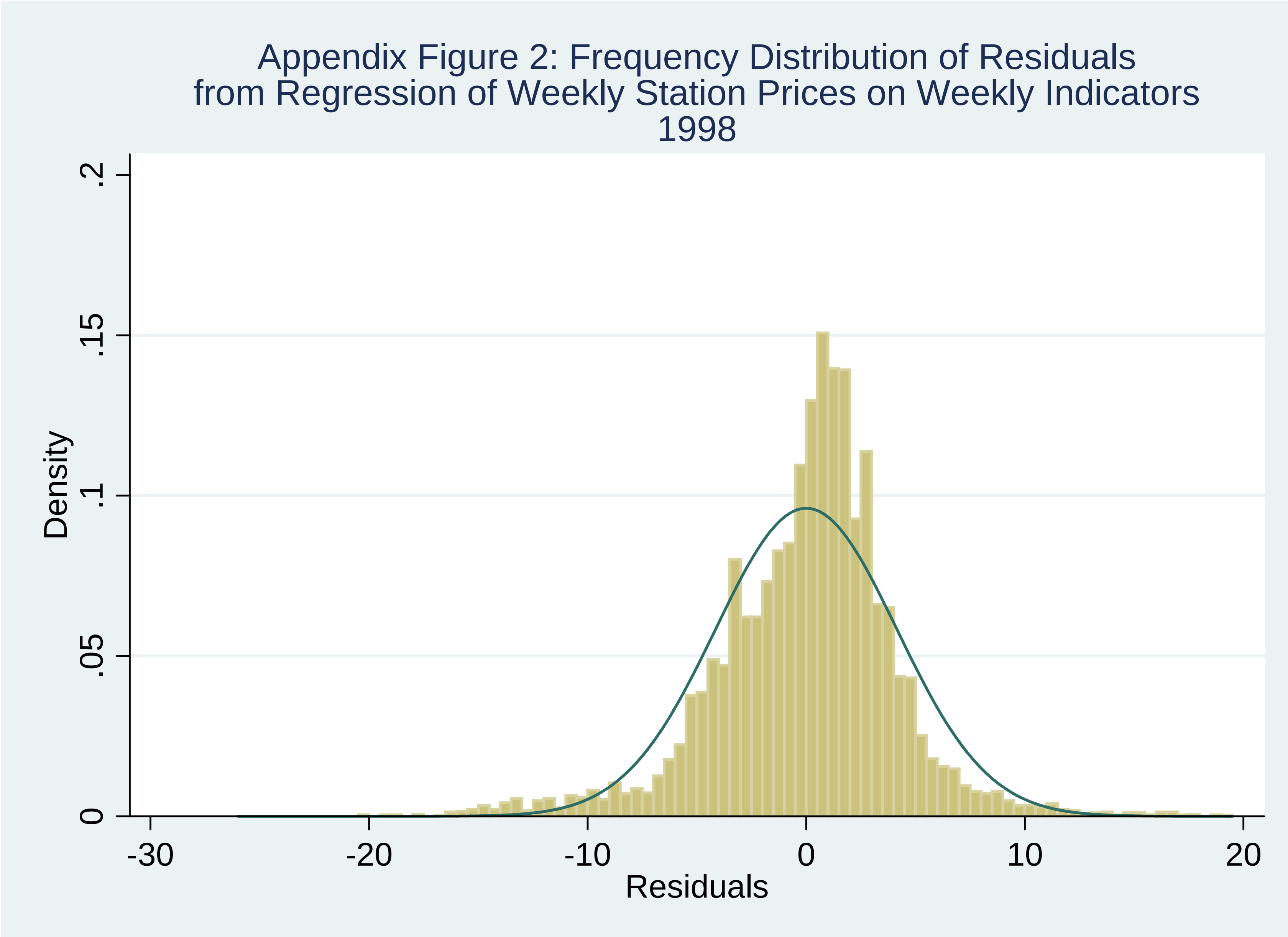
Appendix Table 1: Single-Period Empirical Markov Transition Matrix
(Residuals from Regression of Price on Week Indicators)

	Relative Price at t+1																				
Relative Price at t	-10+	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10+
-10+	**0.78**	0.09	0.04	0.03	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-9	0.27	**0.32**	0.17	0.09	0.05	0.03	0.03	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
-8	0.09	0.15	**0.30**	0.23	0.11	0.05	0.03	0.03	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
-7	0.04	0.05	0.10	**0.38**	0.24	0.08	0.03	0.03	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-6	0.01	0.01	0.03	0.11	**0.47**	0.23	0.06	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-5	0.01	0.01	0.01	0.03	0.15	**0.43**	0.24	0.06	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-4	0.00	0.00	0.01	0.01	0.05	0.15	**0.44**	0.24	0.05	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-3	0.00	0.00	0.00	0.01	0.01	0.04	0.16	**0.45**	0.21	0.05	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-2	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.15	**0.41**	0.26	0.05	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-1	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.14	**0.43**	0.24	0.06	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.13	**0.47**	0.24	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.05	0.16	**0.49**	0.19	0.04	0.02	0.01	0.01	0.01	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.18	**0.44**	0.18	0.04	0.02	0.01	0.01	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.08	0.18	**0.45**	0.13	0.04	0.01	0.01	0.01	0.00	0.01
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.07	0.11	0.19	**0.37**	0.12	0.04	0.01	0.01	0.01	0.01
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.04	0.09	0.12	0.17	**0.34**	0.11	0.02	0.01	0.01	0.02
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.09	0.13	0.11	0.15	**0.26**	0.10	0.04	0.01	0.01
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.06	0.10	0.11	0.08	0.11	0.10	**0.25**	0.07	0.03	0.03
8	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.01	0.04	0.06	0.05	0.08	0.05	0.08	0.14	0.08	**0.16**	0.11	0.08
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.02	0.09	0.06	0.07	0.09	0.08	0.08	0.09	0.04	**0.19**	0.17
10+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.05	0.02	0.04	0.04	0.03	0.02	0.02	0.03	0.04	**0.64**

Appendix Table 2: Single-Period Empirical Markov Transition Matrix
(Residuals from Regression of Price on Store and Week Indicators)

	Relative Price at t+1																				
Relative Price at t	-10+	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
-10+	**0.45**	0.15	0.05	0.05	0.04	0.05	0	0.05	0.02	0	0.07	0	0	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00
-9	0.08	**0.20**	0.22	0.12	0.16	0.06	0.06	0	0.04	0	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-8	0.07	0.08	**0.12**	0.20	0.15	0.10	0.07	0.12	0.02	0.02	0.03	0.02	0	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
-7	0.05	0.02	0.08	**0.26**	0.20	0.18	0.10	0.02	0.06	0.02	0.01	0	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
-6	0.02	0.02	0.04	0.15	**0.23**	0.19	0.11	0.06	0.05	0.06	0.03	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-5	0.00	0.01	0.01	0.03	0.09	**0.29**	0.26	0.10	0.08	0.05	0.03	0.03	0.01	0.01	0.01	0	0	0.00	0.00	0.00	0.00
-4	0.00	0.00	0.01	0.01	0.04	0.10	**0.30**	0.26	0.08	0.07	0.04	0.05	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
-3	0.00	0.00	0.00	0.00	0.00	0.02	0.09	**0.36**	0.28	0.09	0.06	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-2	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.11	**0.40**	0.28	0.08	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0	0.00
-1	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.13	**0.46**	0.25	0.05	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.05	0.18	**0.47**	0.21	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.07	0.21	**0.45**	0.16	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.001	0.00	0.00	0.00	0.01	0.01	0.03	0.06	0.10	0.22	**0.39**	0.13	0.03	0.01	0.01	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.06	0.11	0.19	**0.37**	0.12	0.02	0.01	0.01	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.05	0.07	0.09	0.10	0.18	**0.27**	0.12	0.03	0.01	0.00	0.00	0.01
5	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.08	0.06	0.07	0.09	0.15	**0.31**	0.10	0.02	0.01	0.01	0.02
6	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.07	0.04	0.04	0.06	0.06	0.06	0.12	0.12	**0.24**	0.10	0.00	0.00	0.02
7	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.08	0.08	0.05	0.10	0.07	0.10	0.07	0.13	**0.19**	0.02	0.02	0.01
8	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.05	0.05	0.05	0.07	0.02	0.02	0.07	0.05	0.10	0.10	0.05	**0.07**	0.07	0.20
9	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.13	0.06	0.09	0.13	0.03	0.16	0.03	0.06	0.00	0.03	0.06	0.00	0.03	**0.13**
10+	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.03	0.02	0.05	0.04	0.03	0.04	0.03	0.03	0.01	0.02	0.01	0.03	0.00	0.67


Appendix Figure 1: Frequency Distribution of Residuals
from Regression of Weekly Station Prices on Weekly Indicators
1997
Density
0
.05
.1
.15
.2
-30
-20
-10
0
10
20
Residuals



Appendix Figure 2: Frequency Distribution of Residuals
from Regression of Weekly Station Prices on Weekly Indicators
1998
Density
0
.05
.1
.15
.2
-30
-20
-10
0
10
20
Residuals

Appendix Figure 3: Frequency Distribution of Residuals
from Regression of Weekly Station Prices on Weekly Indicators
1999